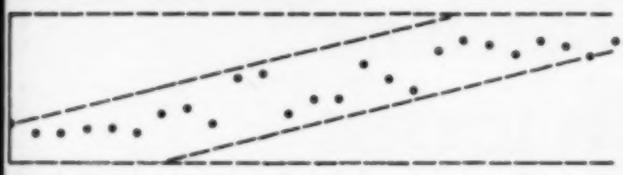
Industrial QUALITY CONTROL

VOL. III SEPTEMBER, 1946 NO. 2



Quality Control Charts maintained by the operator will insure maintenance of dimensions on these four spindles and will give advance notice of any tendency toward out-of-round or off-center drilling.

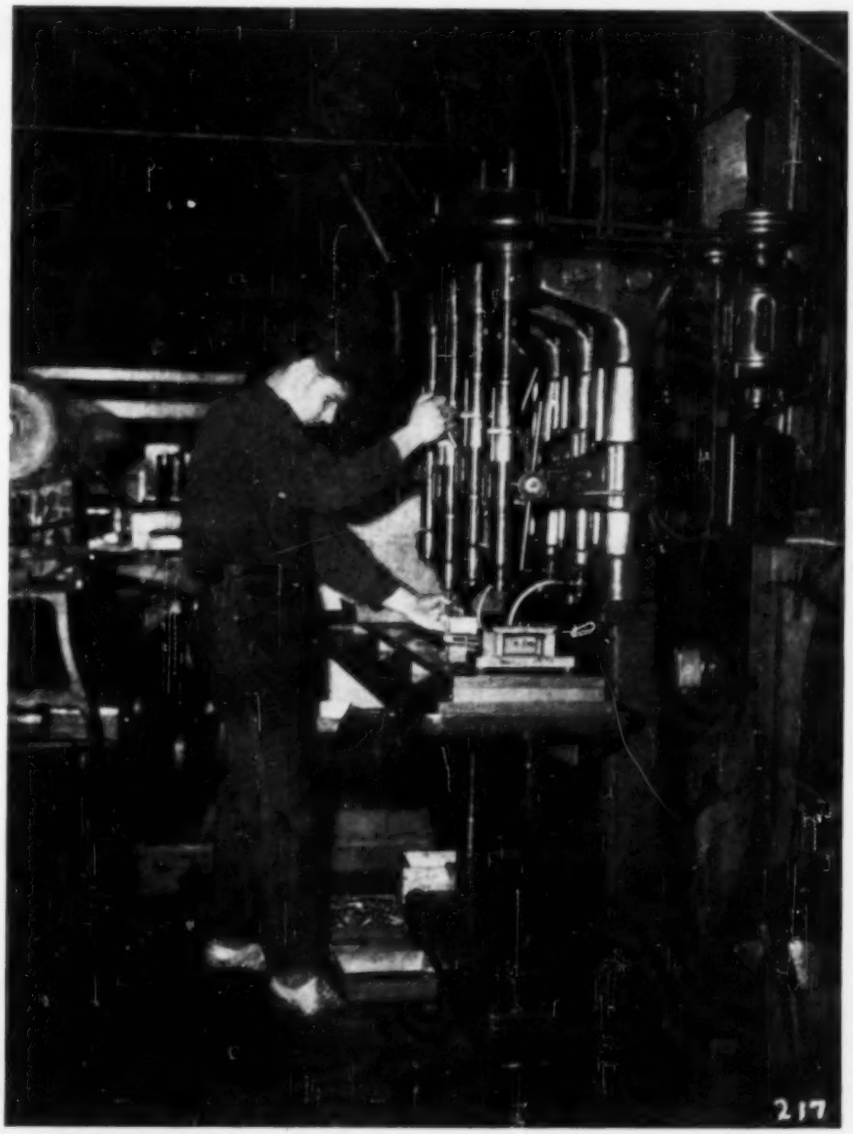
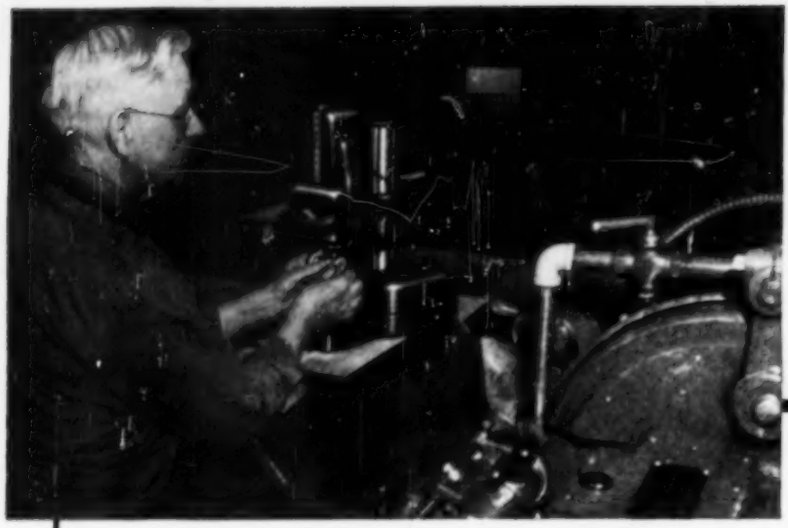


Photo courtesy of Buffalo Forge Co.

AMERICAN SOCIETY FOR QUALITY CONTROL



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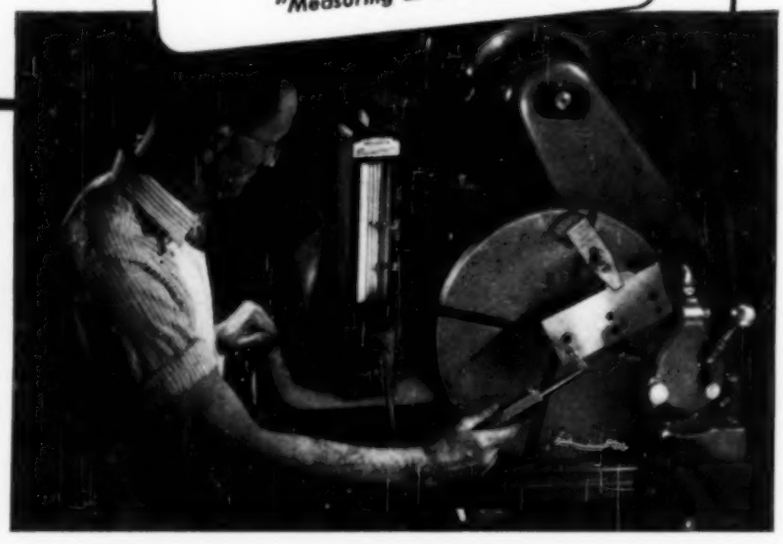
chek with Sheffield on "Measuring at the Machine"

1767



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Committee On Publicity and Public Relations Completed

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LOCAL SOCIETY REPORTS

In the following local Society Sections, 100% of the local members are now also members of the American Society for Quality Control:

Boston Society for Quality Control.
Society of Quality Control Engineers of California.
Society for Quality Control—Georgia Group.
Illinois Society for Quality Control.
Society for Quality Control—University of Iowa Group.
Michigan Society for Quality Control
Ohio Quality Control Society.
Society for Quality Control—Omaha Group.
Pittsburgh Quality Control Society.

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Membership in The American Society for Quality Control is available through local society sections or directly through the Executive Secretary. Annual dues are five dollars for direct national membership. Information concerning local societies should be obtained from local secretaries.

Founding Memberships in the Society are available prior to July 1, 1947 by an additional payment of five dollars or more.

General Information

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COST OF BACK ISSUES

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INDUSTRIAL QUALITY CONTROL
was founded in 1944 by the
SOCIETY OF
QUALITY CONTROL ENGINEERS
BUFFALO
in cooperation with
THE UNIVERSITY OF BUFFALO

Committee on Constitution and By-Laws Completed

Appointment of the following Committee on Constitution and By-Laws is announced:

Mr. Frederick J. Halton, Jr., Chairman.
Mr. James M. Ballowe.
Professor Paul C. Clifford.
Mr. Halsey H. Kent.
Mr. John M. Howell.
Mr. Ernest H. Robinson.

As is well known, the present Constitution and By Laws was drafted last Winter under the considerable pressure attendant upon the desire for immediate activation of the American Society. Much of this work was done by Mr. Halton with the able assistance of several of the other members of the new committee now appointed. Mr. Halton was the first to suggest the desirability of a careful revision and polishing up of the present Constitution and By Laws, and he has kindly consented to serve as Chairman of the new Committee.

The new Committee does not have in mind any immediate changes in the Constitution and By Laws. Rather, it contemplates presenting a complete redraft, which would incorporate provisions to take care of further needs already experienced since the Society has become a going concern, and which could be considered for ratification by the membership in the postal ballot at the time of the election of officers in June, 1947.

Committee On Professional Ethics And Qualifications Completed

Appointment of the following Committee On Professional Ethics And Qualifications is announced:

Mr. Charles J. Hudson, Chairman
Mr. P. L. Alger
Mr. G. Rupert Gause
Mr. Halsey H. Kent
Mr. Russell F. Passano
Dr. Hugh M. Smallwood
Dr. S. S. Wilks

THIRD REPORT OF MIDWEST Quality Control Conference

Reporting Quality Results to Management

MARTIN A. BRUMBAUGH

PROFESSOR OF STATISTICS, UNIVERSITY OF BUFFALO

[**Presented at Luncheon March 6**]

This subject presupposes that a quality control operator has been at work in a plant and has obtained some results that are worth reporting. In making such report he must recognize that: (a) there exists a great variety of types of plant operations, (b) a great variety of points of view of quality control operators, (c) a great variety of attitudes of management. Each of these factors must be taken into account in planning a reporting program. Accordingly what follows here must be interpreted in terms of conditions existing in a particular plant. In general a quality control operator earns his salary by possessing two types of ability: (a) knowledge of where to find things in a book, (b) knowledge of when to abandon the book in favor of his own ingenuity.

The operator who is in the fortunate position of working with management that understands the technique of statistical control can report in detail everything that he is doing. In fact, keeping management fully informed is the best method of maintaining interest in the work. Even under such favorable conditions, summary reports should be submitted at strategic times.

If management is open-minded but uninformed on statistical control, the first requirement is to do some sugar-coated instructing in the subject. But the exact procedure must be geared to the personalities involved, both management and operator. The author has seen the successful use of three entirely different techniques. There must be others that have been used with equal success.

(1) The probability approach: set up examples with cards, dice, or colored beads to show chance variability; plan the experiments so that they will be applicable to the plant's manufacturing operations.

(2) The control chart approach: tell the story of separating chance variability from assignable causes of variability; show the frequency distribution analysis and application to plant operations; present the principles of sampling, preferably with examples of potential or actual savings.

(3) The indirect approach: forget statistical control and tell the story solely in terms of operations and results obtained; bring in the control chart as an operating device, and keep the statistical background out of the presentation.

If management is only lukewarm or even hostile, great care is required. Believing that this case requires the greatest amount of discussion, two cases are presented in the sequel in which quality control operators succeeded in converting hostile managements.

CASE I

The quality control engineer operated two levels below the quality manager who reported directly to the plant superintendent, the responsible policy-making executive. Initially the quality control engineer was authorized by his supervisor to analyze records of inspection of assembly operations. The engineer prepared charts of number of defects per unit and posted them at all assembly stations. Simultaneously he inaugurated a system of weekly reports. These reports were circulated to foremen of inspection and production as well as to the quality manager and plant superintendent. There was no evidence that the executive paid the slightest attention, but the quality of assembly work improved steadily.

At the end of three months the engineer submitted a report which compared the man hours per unit in assembly, inspection, repair and replacement, and reinspection before and after using statistical control. Included also was a comparison of the number of units accepted by the Army in the two periods. The marked improvements indicated by this table finally drew the plant superintendent's attention, and he ordered an expansion of the statistical department with instructions to investigate fabrication operation and receiving inspection.

The machine shop, although producing 400,000 piece parts per week, was characterized by short runs, sometimes making as many as 800 part numbers in one week. Control chart analysis of an operation of this type was not attempted even though the initial record of 15% reworked and 4% scrapped indicated plenty of room for improvement. Instead, a weekly report was circulated to management and to shop supervision. This report gave a record of the quality of production in the machine shop, showing the number and percent

of pieces accepted and rejected for both the current week and for the preceding ten weeks. The report also included an analysis of rejected pieces, showing cause of rejection, rework data, and scrap loss.

Just as in the assembly area, this report received scant attention, and for several weeks no improvement was shown. A chronic rework was defined as an item for which at least 10% of production was returned to the machine shop for at least three successive weeks. This supplementary information finally caught the eye of the plant superintendent, and action followed quickly. Individual foremen were called in for specific explanations. The usual attempt to "pass the buck" was stopped short by the detailed inspection records presented by the control engineer. Corrective action was swift and permanent. The results after seven months of reporting were excellent.

A report to the plant superintendent stressed the fact that in 1944 one piece out of six passing through the shop and passing to the inspection bench was covering the route a second time. Stated differently, this meant that one-sixth of the machine capacity of the shop was ineffective and that inspection costs were inflated by 20%. This situation was automatically corrected by the reduction in reworks in 1945. This report was made to offset the shop supervision contention that reworks were inexpensive.

A parallel reporting procedure was set up for receiving inspection, but its effect was negligible until the control engineer prepared a vendor rating sheet and submitted it to the purchasing department. This sheet showed the average percent defective of inspected samples or lots for each individual part number supplied by the respective vendors. The first one was made for a list of standard parts. Subsequent ones were made for the list of special parts going into a single sub-assembly. Purchasing discovered the parts for which a particular vendor could maintain good quality, as well as the vendor or vendors that could maintain good quality on a particular part number. A supplementary sheet showing the number of rejected lots during the month returned to each vendor, quickly revealed the source of most of the costly follow-up work of the purchasing department. On the basis of this rating sheet the purchasing department rearranged its contracts, assigning to each vendor the part numbers which that vendor could do best. A few vendors with uniformly poor quality records were dropped. The effect of this arrangement was apparent on the rating sheets of subsequent months.

The reports described are only a sample of the work done by this control engineer. He adhered to the point of view that corrective action should be the responsibility of production, but that it was his task to provide as much detailed information as possible to aid production. He made no spectacular attempts to attract the attention of top management, but rather depended upon the cumulative effect of repetitive reporting. He did come to three conclusions: (1) immediate superiors with no knowledge of quality control procedure and no desire to acquire such knowledge are a hindrance to progress despite good intentions; (2) top management must possess some knowledge of quality control procedure and a genuine interest in using control results as a management tool; (3) there is no method of evaluating or reporting the intangible gains from the use of statistical control; hence evaluated dollar savings are always an underestimate of the benefits of a control system.

CASE II

The chief inspector of this plant reported directly to the factory manager and within his own function possessed sufficient authority to introduce statistical control procedure as an integral part of inspection operations. This was done initially in the assembly area because this plant does comparatively little fabrication, although many special parts are machined in the plant.

Over a span of three months considerable improvement in assembly operations resulted from daily and weekly reporting of the results of inspection. When out-of-control conditions were encountered, immediate investigation followed. In some cases this led directly to receiving inspection. Detection of quality variation there led in several cases to the dispatch of trouble shooters to plants of vendors. In other cases assembly failures were quickly traceable to faulty machine shop operations. In still other cases it was found that piece parts and sub-assemblies were being damaged during assembly. In a few cases blue prints were changed on the basis of the control chart records. Corrective action produced results which were recognized by operating supervision throughout the plant, but top management gave no evidence of being aware of the existence of the quality control system until the chief inspector prepared a summary which showed the steady and striking improvement in percent defective in assembly operations during the first three months of corrective action based on control chart records.

This report produced ample response from top management, and the chief inspector was authorized to install statistical control on all operations in the plant. The chief inspector is very meticulous about placing on the President's desk periodic summary reports of the quality status of all operations.

In passing, several other experiences can be mentioned briefly. A quality control manager planning the introduction of statistical control "sold" the idea to top management and secured a general directive authorizing him to install his system. He then began issuing orders to operating departments, but did not train men in his own inspection department in control chart technique or corrective action procedure. Needless to add the results were disastrous. This man was shortly transferred to another plant and soon left the company.

In another plant, a new Vice-President in charge of plant operations announced that all emphasis must be placed on two departments: production and selling. Pursuant of this plan, the inspection department was skeletonized and a flourishing statistical control installation was abandoned. Three months of this policy has resulted in the loss of a long-standing contract to make an important sub-assembly for a large automobile manufacturer. The author strongly suspects that the future of this company is directly bound up with the

selection of a new Vice President in charge of operations.

Because conditions vary so greatly from plant to plant, there is little possibility that any usable rules can be stated for reporting quality control results to management. The following, which are little better than guesses, may have some guidance value:

(a) Present summaries, not details.

(b) Make it simple, but be sure to tell the story.

(c) Dollar savings are most effective, but dollar figures often breed controversy. Perhaps a man-hour report will serve better than a dollar report.

(d) Modesty is essential; overmodesty may be fatal.

(e) No harm will come from allowing a small amount of residual mystery to inhere in the expression "statistical control."

(f) Concrete results will attract attention; do not waste an executive's time with reports of pious hopes.

Quality Control by Statistical Methods Applied to Line Production

E. F. GIBIAN

CHIEF INDUSTRIAL ENGINEER, THOMPSON PRODUCTS, INC. AND THOMPSON AIRCRAFT PRODUCTS CO.

[**Clinic 10**]

I. **An Example Used for Illustration.** The application of statistical control procedures to line production may best be illustrated by a specific example. The examination of the procedures, results, and experience gained in a particular case may then be used to illustrate the general principles of a line production quality control system.

The example used for this purpose is taken from the plant of the Thompson Aircraft Products Co., and deals with the manufacture of automotive valves. These valves are produced in a line, where the product moves from operation to operation without backtracking in a continuous production stream from start to finish. This is a typical example of comparatively simple straight-line mass production of an article of high precision.

The setting up of these production lines had to be started almost overnight after V-J Day, and completed in a very short time. The hurried move necessitated by this change-over from war production to peace-time production was naturally accompanied by considerable confusion, and the efficiency of these lines at the start of production was, of necessity, very low. It became immediately apparent that steps had to be taken to raise the efficiency of these lines by an intelligent industrial engineering approach. The objectives of this approach were to reduce the cost of direct and indirect labor, especially inspection; to improve machine utilization; to reduce the inventory in process; to reduce repairs and scrap; and to raise the quality level of the product and the quality-mindedness of the entire working force.

To accomplish these objectives, provisions had to be made to obtain revealing and accurate performance data so as to establish good manufacturing control based on concise and accurate reports. The installation of daily budgetary control reports became imperative, and was one of the first steps initiated in the industrial engineering program. As soon as this was accomplished, the need for the second step became apparent; namely, the need for statistical control of the process.

Figure 1 illustrates a typical valve forging as it is delivered to the start of the valve machining line. It is made from a heat resisting alloy steel which is not readily machinable, and particular care and ingenuity are required in developing the tooling and various fixtures used in the subsequent machining operations.

Figure 1, VALVE FORGING

Figure 2 illustrates the finished product made from such a forging. The seat, stem, and face of the stem are ground; the balance of the surfaces machined. The two grooves near the end of the stem are the retainer grooves for the valve lock. They have to be accurately located in relation to the seat, and the seat, stem, retainer grooves, and stem face have to be concentric and square to each other, as applicable, to rather close tolerances.

The progress of the product from operation to operation is shown in schematic fashion in Figure 3, which illustrates the main steps.

II. **Formulation of a Quality Control Program.** When the production on this line was started, as

Figure 2, COMPLETED VALVE

many as 30% of the valves flowing through the line had to be returned for repairs at one point or another. The percentage of rejects at final inspection was excessive. When the cost of inspection was analyzed, the figures were also discouraging. A closer examination of inspection procedures disclosed that efforts were often misdirected, and that the inspection results were in no way commensurate with inspection efforts. A plan for improving quality control was therefore formulated, and the quality control group was given the following assignment.

1. Study each operation in a line from the quality control standpoint.
2. Wherever feasible, apply statistical methods to chart the frequency distribution in order to determine if this particular operation is, or may be, brought under control. At the same time, analyze the distribution of the present inspection force, and estimate inspection savings if statistical quality control could be made effective.
3. Collect accurate records of all rejects, scrap, and reworks by operations and by operators.
4. Study the effect of out-of-control conditions on subsequent operations in the line, and point out difficulties which may be caused by such conditions.
5. Study current manufacturing tolerances, and analyze the effect of these tolerances on the particular operation to which they apply and on subsequent operations.
6. The quality control group is to be given full authority on one machining line. Control chart procedures are to be installed, and the quality control department will have the authority to call for tool adjustments and methods changes wherever indicated. The quality control group will also have authority to redistribute or reduce inspection personnel as control chart procedures are installed.
7. Relate and coordinate the activities of the quality control group with standard engineering and the budgetary control program.

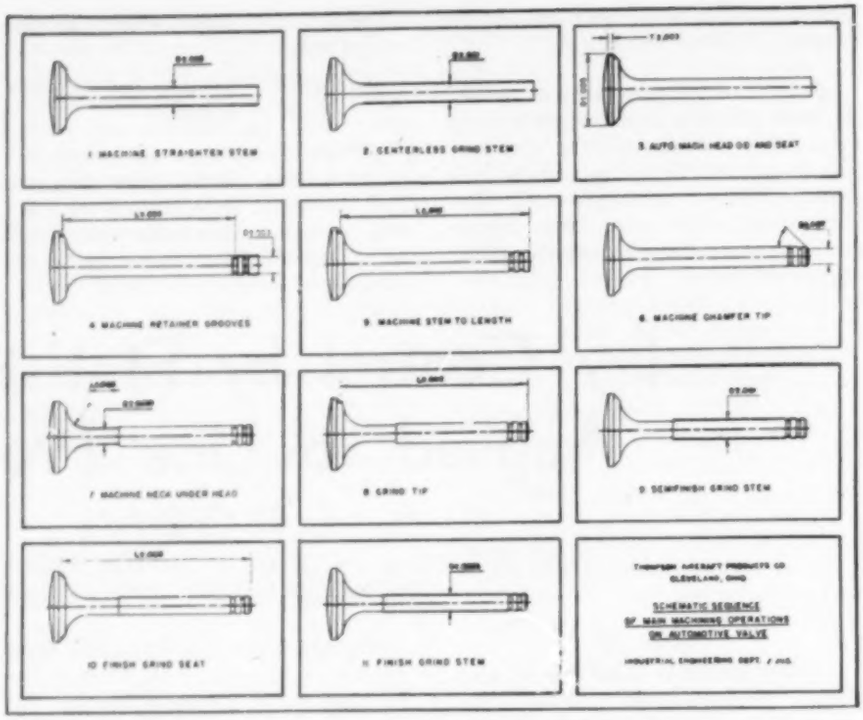
1. MACHINE STRAIGHTEN STEM
2. CENTERLESS GRIND STEM
3. AUTO MACH HEAD OD AND SEAT
4. MACHINE RETAINER GROOVES
5. MACHINE STEM TO LENGTH
6. MACHINE CHAMFER TIP
7. MACHINE NECK UNDER HEAD
8. GRIND TIP
9. SEMIFINISH GRIND STEM
10. FINISH GRIND SEAT
11. FINISH GRIND STEM
SCHEMATIC SEQUENCE
OF MAIN MACHINING OPERATIONS
ON AUTOMOTIVE VALVE

Figure 3: SEQUENCE OF OPERATIONS IN THE LINE

This last point may sound rather unusual, but it is a very important step because quality control should be concerned not only with the quality of the product, but also with any cost reduction program. Labor standards are established on the basis of existing conditions. When statistical control is applied, it very often brings about such radical changes that standards must be adjusted accordingly if full benefits are to be derived from the activities of the quality control group.

Daily budgetary procedure should reflect any accomplishments obtained by the installation of successful quality control methods. Factors used in a budgetary control system are therefore adjusted according to the progress made by the quality control program. The amount of operating labor is budgeted and related to the number of set-ups, inspection supervision, inspection labor, replacement tools, grinding wheels, and other items. Any improvements in the use of direct labor, inspection, tools, and grinding wheels—to cite a few examples—call for the adjustment of budget factors to reflect the changed conditions. By such a tie-in of the quality control work with the functions of other departments concerned with the operating efficiency of the plant, quick and permanently good results are obtained.

III. **Preliminary Findings.** Studies were made on each operation in the valve line under existing conditions, results were charted, and all pieces were 100% inspected. As soon as data were assembled, and averages and ranges determined, control chart procedures were installed. Quality control engineers directed tool adjustments and methods changes, and the results were again checked by 100% inspection. When any particular process was reasonably well under control, a regular control chart procedure was established and turned over to the inspection personnel, although the quality control department kept a constant check and continued to give advice.

The preliminary findings of this survey revealed that the majority of the operators ran towards the high side to avoid scrap: they played safe. This practice was the source of too many reworks and repairs. Especially inexperienced help had the natural tendency to stay on the safe side, and results obtained from several machines used on the same operation were, therefore, very erratic and caused frequent interruptions or delays in the progress of the work through

the line. The improvement of this condition, and the almost total elimination of these difficulties, will be brought out later by comparing the conditions existing before the various processes were brought under control with the conditions existing after statistical control was established.

IV. **Statistical Control of Individual Operations.** The first operation of roll straightening the valve forging is not covered by a control chart procedure. Operation No. 2, rough grinding the stem on a centerless grinder, is similar to the finish grinding operation, No. 11, and the results obtained on all three centerless grinding operations will therefore be illustrated by the example given for operation No. 11.

The machining of the circumference and the seat of the head is done on a single spindle automatic. Pieces are fed from a hopper to an automatic feed which inserts the valve in the chuck. Tools on the front and back slide perform the machining operations, and the valve is automatically ejected when the cycle is completed.

The left portion of the control chart, Figure 4, illustrates the performance of one of these machines before the control chart procedure was applied. The average was fairly close to the drawing mean, which is indicated by $\bar{X}'$. The average range was satisfactory, but it can readily be seen that the process was not under control, and that the operator did not know when or how to make his tool adjustments in order to keep the pieces within the specified tolerances. Consequently, many pieces had to be reworked, as indicated by the points above the upper control limit, and a considerable number of pieces became scrap, as indicated by the points falling below the lower control limit. The right hand portion of the chart clearly illustrates the marked improvement obtained by the control chart procedure. Although the mean average, $\bar{\bar{X}}$, is slightly above the drawing mean, both ranges and averages are well under control.

As an additional help in appraising the process, the mean range, based on a selected σ' is shown on the chart. The selected mean range is indicated by the line $d_2\,\sigma'$, and the corresponding upper

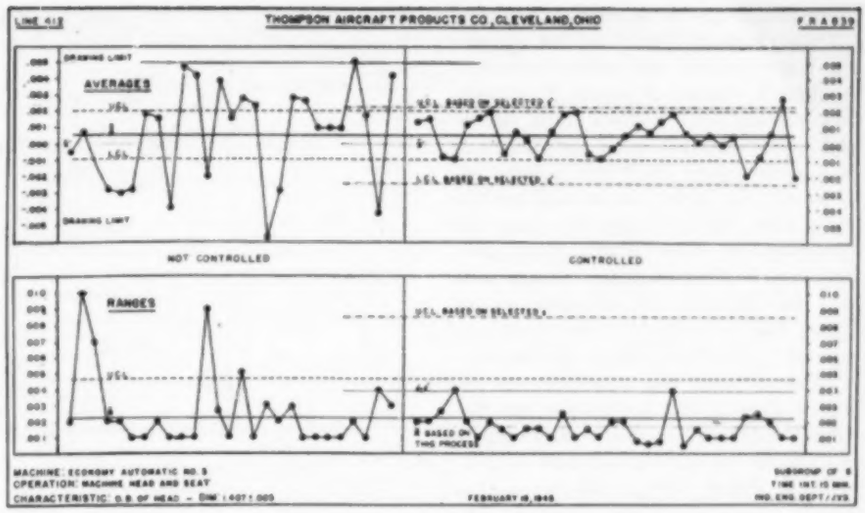

Figure 4: CONTROL CHART FOR OPERATION NO. 3

and lower limits for averages, based on the selected σ', provide an auxiliary method for judging how this process fits the drawing specifications. This chart shows the record from one machine, but several machines are used on the line for the same operation. After bringing all the machines under control by the control chart method, the 100% inspection previously necessary was eliminated, and the high percentage of repairs also disappeared.

The machining of the retainer grooves is a very fast operation, performed on a single-spindle Brown and Sharpe automatic. It requires only loading and unloading of the valve. Originally, one operator ran one machine and inspected all the valves on a "go" and "no-go" gage. When the statistical studies disclosed that the process stayed in control, a modified statistical control was established by providing the operator with an additional set of gages set to the upper and lower limits of the process for individual pieces. The operator now checks the first twelve pieces after each set-up, and from then on he checks approximately every fiftieth piece on the control limit gage. It thus became possible to assign two machines to each operator and obtain considerable savings.

Machining the stem to length, operation No. 5, is done on a conventional screw machine provided with a fast loading fixture. Several machines are in the production line, and the accuracy of the pro-

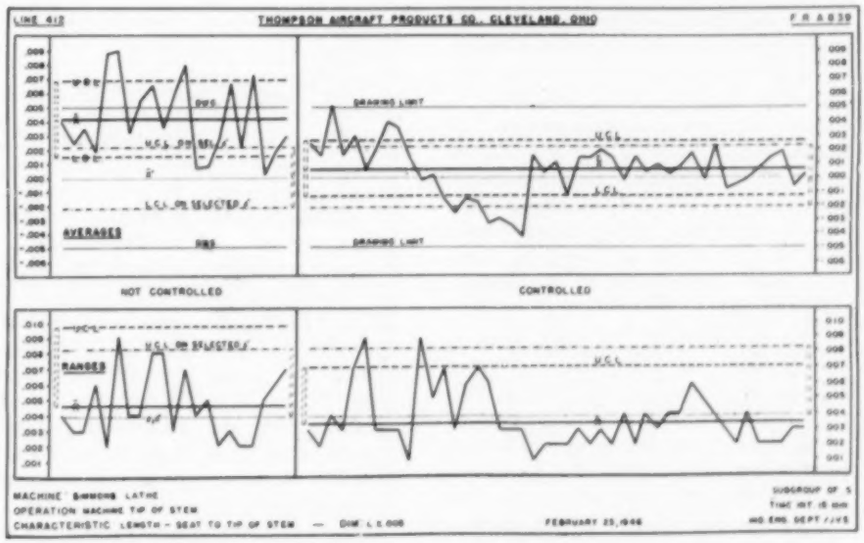

Figure 5: CONTROL CHART FOR OPERATION NO. 5

cess depends, to a certain extent, on the trained "feel" of the operator because the tool slide is moved by hand. Figure 5 again illustrates the conditions before and after statistical control was established. It can be seen that the rather inexperienced operator stayed on the safe side, his average running approximately .004" above the drawing mean. The average range was too far above the selected $d_2\,\sigma'$. After the control chart was put into use to bring the process under control and help the operator to acquire the correct technique, an entirely different picture developed, as shown in the right-hand portion of the chart which illustrates the process coming under control. The average was brought very close to the drawing mean, the range reduced, and the entire lot eventually was well within the drawing limits. This was an important operation to bring under control, because the maintenance of an accurate length from the seat to the tip has a bearing on the later operation of grinding the tip. As long as the level varied with operators, numerous troubles arose in tip grinding. The control chart helped to obtain uniformity from several machines, showed the way for improving the technique of the operators, gave confidence to less experienced men, and increased the tool life. It also pointed the way to a methods improvement; namely, the substitution of an automatic hydraulic feed for hand feed.

The next operation, No. 6, the chamfering of the tip end, is performed on a simple screw machine. The tolerances are inconsequential, and statistical control is not needed to keep the job running within the drawing limits. Operation No. 7, machining the undercut under the head, is performed on the same type of automatic single-spindle machine as is used in operation No. 3, and the same experiences and results were obtained by control chart procedures as on operation No. 3.

The grinding of the stem face is performed on a disc grinder equipped with an oscillating fixture. This requires a certain amount of skill because the man loads the valves by hand and the pressure against the grinding wheel is controlled by the "feel" of the operator. Control charts applying to this operation (Figure 6) show the comparison of conditions on two machines, each run by a different operator. Machine No. 1 with operator No. 1 applies to a fairly experienced operator; whereas machine No. 2, manned by operator No. 2, applies to a less experienced man. While the more experienced man held his average close to the drawing mean, and was also able to hold the pieces within a lesser spread than the operator on machine No. 2, neither one of the two cases was satisfactory. It is interesting to note that with the help of the control chart, not only was it possible to narrow down the range considerably, but also the averages could be held practically to the drawing mean. Closer limits than those called for by the drawing specifications are now held by the controlled process. This greater uniformity helps very much in the later operation of seat grinding, because it is not now necessary to separate the lots from various machines, nor is it necessary, in the later operation of seat grinding, to change the set-ups to suit such varying lots. This may be considered a typical example of how control chart procedures become a real help in straight-line production where there is interdependence of operations that have to be performed without changes in set-ups.

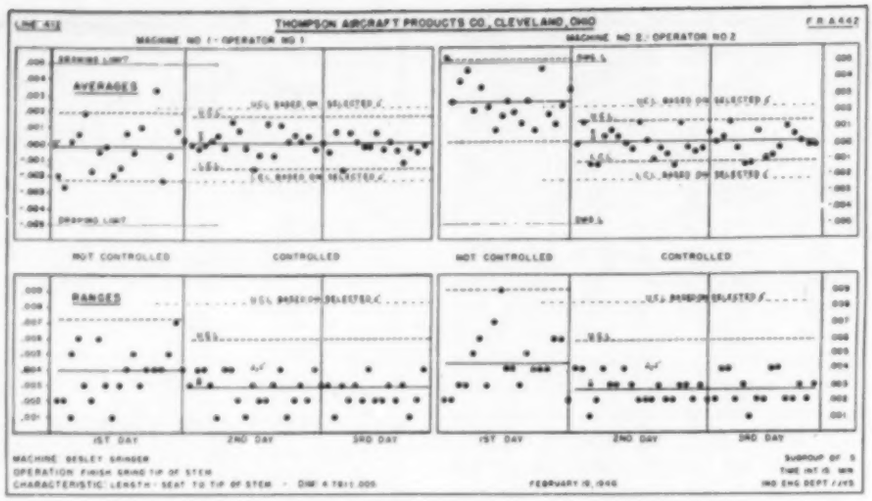

Figure 6: CONTROL CHART FOR OPERATION NO. 8

The grinding of the seat, operation No. 10, is a critical step in the manufacture of the valve. The seat forms the sealing surface of the valve, and therefore has to be properly finished, kept to accurate

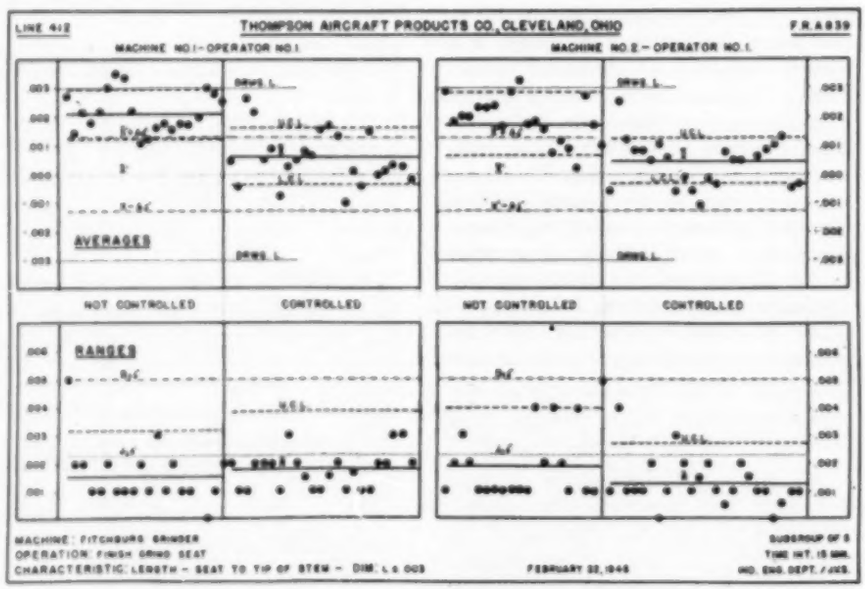

Figure 7: CONTROL CHART FOR OPERATION NO. 10

dimensions, run concentric with the stem diameter, and a gaging diameter on the seat has to be in close relation to the tip face of the stem. The manufacturing set-up is a semi-automatic machine requiring only the loading and unloading of the valve; the rapid traverse, and the infeed of the grinding wheel, as well as the retraction of the grinding wheel slide and the dressing of the wheel, being performed automatically. One operator runs two machines, and several pairs of these machines are on each line. The operators worked more or less in the dark and were rather uneasy about their jobs, because the scrapping of almost finished valves at this point is costly. The chart shown in Figure 7 for machines No. 1 and No. 2 run by the same operator, indicates that the man was not able to hold to the drawing mean and hesitated to make the proper adjustments. Without the control chart as a guide, the operator lacked the knowledge of where and how to adjust the machine in order to stay within the specified limits. With the process under control, no appreciable change occurred in the range, which is understandable because of the semi-automatic feature of this grinder, but the averages were brought and maintained very close to the drawing mean.

A quick study of the chart will reveal the savings obtained through the elimination of repairs and rejects. It should also be kept in mind that a uniform product was obtained from a number of machines used on this operation. Finally, it is worthwhile to note that the conditions illustrated on these charts were obtained after the tip grinding was brought under control. The valve is located in the grinder against the finished face of the tip, and the variations were greater than those shown on this chart before the tip grinding was brought under control.

The finish grinding of the stem, operation No. 11, is a conventional centerless grinding operation calling for comparatively close limits of ± .0005". Figure 8 shows that the operator was doing a fairly good job before the control chart procedure was put into effect, except that he was again running rather on the high side to avoid scrap. There is evidence of some assignable causes which are,

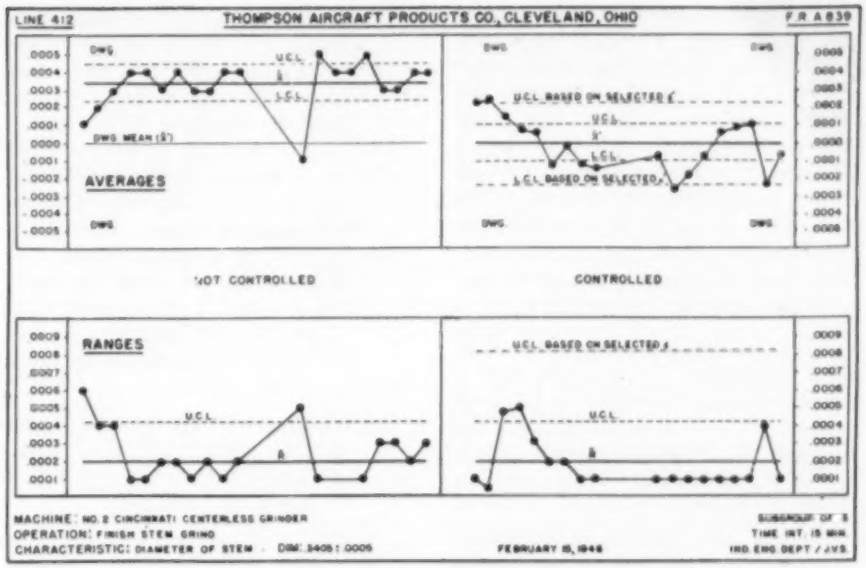

Figure 8: CONTROL CHART FOR OPERATION NO. 11

no doubt, derived from the nature of the process, requiring, as it does, hand feeding and hand closing of the regulating wheel. Although the operator has time to check his work 100% on a "go" and "no-go" gage, the control chart helped considerably to bring the process closer to the drawing mean, and a steady improvement is noticeable. Incidentally, the use of control charts helped to eliminate the unnecessary dressing of the grinding wheels, and increased the length of the run between dressing operations by approximately 25%. This is an example of the helpfulness of the control chart even though the machine operator has enough time between each cycle to check every piece coming off the machine.

The final inspection of the valves at the end of the line requires 100% visual inspection for finish. The dimensional characteristics may be checked by a sampling inspection procedure, as long as the entire process is controlled, so as to maintain a high quality level.

V. **Conditions Prior to the Installation of Statistical Process Control.** The experience with statistical control in the case discussed so far leads to certain general observations which will apply to almost any line production set-up. In general, the drawbacks and difficulties caused by a lack of statistical control will be as follows.

1. Operators with different techniques produce a non-uniform product which is a frequent cause of trouble in subsequent operations.
2. There is a tendency to play safe. The operator hesitates to work to the drawing mean and prefers the risk of producing parts which will require repairs to the risk of making scrap. He makes his set-up accordingly, and the results are loss of production, too many reworks, and too many machines put in the line.
3. The training of new help or inexperienced operators is unsystematic, because the reasons for variations cannot be clearly ascertained. Such conditions delay the attainment of the desired efficiency.
4. Too many inspectors are required. Inspectors are busy checking and rejecting work of poor quality instead of helping to produce work of satisfactory quality.
5. Production planning and scheduling breaks down, because the line output fluctuates when there is no process control.
6. The adequacy of adopted methods is not clearly demonstrated, and very desirable improvements, sometimes of a simple nature, are thus delayed.
7. The quality of the work in process is comparatively low, which necessitates a rigid final inspection with a consequent large amount of rejects.

8. Floor inspection is slow and cumbersome. The large amount of work under inspection and waiting for inspection increases the work in process inventory. Floor space and equipment are poorly utilized. The installation of statistical quality control corrects these conditions and increases the flow of the product through the lines.

VI. **Rules for Statistical Control in Line Production.** Uniformly applicable rules for statistical quality control in line production may be derived from the example dealt with in this article. They may be stated as follows.

1. It is necessary to have a good quality control organization which will coordinate its functions with the activities of other departments concerned with manufacturing, inspection, and industrial engineering.
2. When planning statistical quality control for line production, determine first the operations which lend themselves to statistical control, especially control chart procedures. Using comparatively short runs, make frequency distribution analyses, and draw charts of the conditions as they exist. Where several machines are used in the same operation, be sure to study all of them to determine the difficulties involved and their causes.
3. It has frequently been said and written that one of the first jobs of a quality control engineer is to sell statistical quality control to management. Our experience points in the opposite direction. The real task may well be to sell statistical control to the lower levels, that is, to supervision and workmen. Management, as a rule, eagerly accepts progressive ideas. The quality control engineer must dispel the notion held by foremen and supervisors that control chart procedures will hold up or slow down production.
4. Remember that control charts will prove helpful, even where 100% inspection is feasible or necessary.
5. Pay particular attention to those cases where several machines are running on the same operation. Bring all in line and do away with the necessity of separating lots. Uniformity will thus be secured, which is one of the greatest assets of controlled straight-line production.
6. Not only the quality of the product, but also the life of the tools and grinding wheels is affected by the operators' technique. Control charts point out the better methods, and the knowledge thus gained can be used in the training of operators.
7. When similar products are made on the same line, but from different materials, statistical control is an excellent tool to bring out the differences in the characteristics of these materials, especially if they affect tool design and the materials used in the tools.
8. Where control limits exceed specification limits, do not discard the use of control charts or other statistical helps. In the first place, lots resulting from a controlled process are superior to the lots which were obtained from an uncontrolled process. Through intelligent use of the control chart method it may be possible to find means to vary the process or sequence of operations so that the controlled process eventually will fit drawing tolerances.
9. Finally, by all means, use the information available in statistical studies of a process to point out ways and means to improve the set-up, tooling, or new methods leading to increased production.

VII. **Conclusion.** The example of an automotive valve line will not conform in detail to every straight-line production set-up, yet it represents a clear pattern of how quality control by statistical methods may be applied in general to line production of any type. The benefits accruing to management from this rather new tool of statistical control are well recognized. It is gratifying to know that the workmen are also pleased when they recognize how control chart procedures help them in their work, and that they take pride in their accomplishments. This contribution to employee morale and to the improvement of labor relations adds to the value of statistical quality control and should induce quality control engineers to make full use of it.

The Quality Control Organization

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[**Clinic 3**]

Introduction. In developing the subject of this paper two points of view may be considered. First, the subject lends itself to a discussion of some typical organizations which have been evolved within specific plants to meet specific needs. This approach involves the drawing of organizational lines and a discussion of the level at which quality control enters the organization pattern and to whom it should report. But differences in plant organizations, differences in type of product made, and differences in the personalities of the individuals involved are all factors that influence the character of the quality control organization and the level at which it enters the factory organizational picture. Therefore, it seems desirable to use a second approach, namely, that of defining the responsibilities of the quality control unit and suggesting

some of the functions which it has to perform.

A quality control unit is charged with the responsibility of **interpretation, control, and verification of quality in the manufacturing unit through measurement and/or comparison with the engineering specifications.** In the discharge of this responsibility it has four functions to perform:

1. To provide protection
2. To maintain process control
3. To portray quality performance
4. To train personnel in matters of quality.

I. **The Function of Protection.** In the performance of its first function, quality control has a two-fold obligation. It should provide protection to the producer of the product and protection to the consumer of that product. Quality control is doing its best work in many plants by providing protection to the plant through its receiving inspection, and to the consumer through internal control of the product and final inspection.

One of the first requirements, therefore, of the quality control organization should be that of providing systematic procedures for the control of raw materials, all of which should be required to pass through an inspection station before they are accepted in the plant. In addition, the quality control department should be prepared to exercise its influence in the matter of specifications. Working in close cooperation with the engineering, purchasing, and research departments, it should insist upon purchase specifications that are realistic and test methods that are both accurate and economical in use.

The story is essentially the same for all other types of purchased product, either piece parts, subassemblies, or complete units. The quality control department must again be prepared to enter the picture and insist that specifications be devised which carry meaning to the vendor and which are realistic in terms of the needs of the shop. The quality control department in its daily operations in receiving inspection acquires inspection data which would go a long way toward permitting the purchasing agent to do a more intelligent job of selecting vendors who consistently deliver material of dependable quality. The quality control organization should also watch for data which would support the claim that materials are sometimes ordered on specification at a higher degree of quality and at a higher cost than is actually required in the product. In general, quality control should be in a position to see to it that the plant receives quality protection for each purchasing dollar expended.

Effective quality control serves an equally worthwhile function in providing protection to the consumer. There are many examples in the food and drug industry that suggest the importance of effective inspection and quality control from this point of view. It is the objective of every final inspection group to eliminate the known defective units and to insure that the consumer receives only goods of satisfactory quality. This type of control is of paramount importance to the company, for upon its success rests such factors as good will, competitive advantage, profit and loss position, and satisfaction of the consumers of the product.

It should therefore be a function of the final inspection group to analyze all consumer complaints and to investigate the causes of rejection when goods are returned by the consumer. This function should carry with it the authority to fix responsibility for a defect, and to take appropriate action to prevent its recurrence.

Fundamentally, of course, effective quality control gives the consumer his greatest protection by seeing to it that quality is built into the product. This aspect of the protection function is implicit in the function of process control.

II. **The Function of Process Control.** Some semblance of control can be obtained by an alert inspection organization performing thoroughly the usual sorting and screening which is all too frequently associated with quality control. As the product moves through an inspection crib, the inspector may examine the product very carefully, and by adopting the principle, "It shall not pass," obtain a rather high degree of control. Indeed, through an arbitrary exercise of this authority, he can materially add to the uniformity of product by eliminating as far as possible all known defects. However, it is well known that this is not economical control—it is not quality control. Process control means that an organization has to be so constituted that a number of different activities can be included and integrated. Among these are:

a. The practicability of the design and process should be proved —possibly through a pilot model or pilot lot.

b. Process or floor inspection must be instituted to control quality at the machine.

c. Procedures, such as control charts, must be instituted as means for determining sources of trouble, the causes of a breakdown in quality, and/or any trends which may be developing.

d. Someone must be assigned the responsibility for investigating the unusual variations in quality, establish responsibility for same, and institute corrective action.

In combination with the above duties, the quality control group has another function to perform in relation to gages and the special equipment which is developed for the measurement of quality. Quality of product cannot be controlled unless and until it can be measured. Therefore the quality control organization must insist on three points:

1. That gage manufacturers devise more and more direct measuring instruments.

2. That gage manufacturers devise faster means of gaging.

3. That gage manufacturers devise more accurate and "fool-proof" gaging equipment.

Regarding the first point, direct measuring instruments are prerequisites to the control of quality.

In regard to the second point, gage manufacturers, and particularly those who design and build specialized equipment, should keep uppermost in their minds the question, "Will this device permit economical gaging?"

The third point involves the accuracy and "fool-proof" character of gaging equipment. There are still many instruments in common use which are not adequate for precision measurements, and which permit a high percentage of error on the part of the inspector.

Many studies have been made on the subject of inspector accuracy. These studies have usually been made from the standpoint of rating the inspector on his ability to sort out known defects in a given lot of material. However, one of the most interesting of the recent studies was published in the December 1945 issue of the Journal of Applied Psychology, entitled **Accuracy of Precision Instrument Measurement.** In the study, inspectors in two different plants were examined. Each inspector "was tested on only those instruments which he was accustomed to using. Each was encouraged to make five measurements and then to record his best judgment as to the dimension. The readings thus obtained were compared with so-called 'true' dimensions which were determined by means of ultra-precision instruments in combination with gage blocks. In addition, the instruments utilized in the performance were checked and adjusted periodically to insure (their) constancy." The results were startling.

Using the 1" vernier-micrometer, 43% of the inspectors obtained readings within an established tolerance of ± .0001".

With the 2" vernier-micrometer, 17% obtained readings within the tolerance of ± .0001".

Using the 6" vernier-micrometer, only 11% of the inspectors obtained readings within the tolerance of ± .0001".

Similar tests were made with inspectors using the depth micrometer, and in this case 53% were able to get readings which were accurate within a ± .001" tolerance.

Inspectors using 3" regular micrometers were found to be accurate within ± .001" on 64% of their measurements.

The highest degree of accuracy obtained from among twenty instruments was with the inside micrometer where 66% obtained readings within a ± .001" tolerance. The lowest degree of accuracy came in the use of the inside caliper and measuring over the points with a 6" micrometer. In this case only 9% of the inspectors were accurate within a tolerance of ± .002".

One may be tempted to charge off all of this inaccuracy to "poorly trained inspectors." However, in the study quoted, 45 experienced toolmakers were also examined in a similar fashion, using the vernier-micrometer. It is interesting to note the results. If the part was about ¼" in diameter, 73% of the toolmakers were able to obtain readings which were accurate within a tenth. However, if the cylindrical part was 3 inches in size only 12% of the readings were accurate within a tenth.

In summarizing this study, the authors say, "The implication is present that the very nature of the vernier-micrometer and similar precision measuring instruments is such that one should not expect as high a degree of constancy as the average operator, supervisor and standards man has been taught to expect."

Granting the accuracy of this conclusion in regard to the precision instruments which are the standard measuring devices of the inspector, it is interesting to speculate upon the degree of accuracy which is built into specialized gaging equipment produced by the tool room of the average shop—the equipment with which the quality control unit is supposed to verify quality through measurements!

Another point to be considered by the quality control man is the effect of present type gaging equipment on the use of scientific sampling plans. A little thought on this point will quickly suggest that the quality control man must soon insist upon obtaining gages of the conventional type which are far more accurate than the ones currently produced. He must demand gages which have a minimum gage maker's tolerance, and which have a minimum allowance for wear; in other words, gages which are more nearly representative of the true dimension.

The importance of this consideration can be seen from an examination of a simple application of a recognized sampling plan to the inspection and acceptance of a lot of 500 parts when one is willing to run a 10% risk of accepting a lot as poor as 10% defective, if the acceptable quality level is between 4.01% and 5% defective. According to the sampling table, one takes a sample of 110 pieces, and if no more than 7 pieces of the sample are found to be defective, he accepts the lot. However, if 8 pieces are found he rejects the lot. It can be readily seen that the gage employed in this inspection problem should be one which accurately conforms to the true dimension. The usual allowances for the gage maker and wear would in most instances be sufficient to account for the rejection of a portion of the number which is permissible under the plan, thereby causing rejection of the whole lot. Any savings through sampling would thus be nullified, and detailed inspection would be required.

Objections may be raised by the gage maker on the question of reducing his permissible tolerance. The only answer is that the gage producers **must** make more accurate gages. The shop may even object to having wear allowances minimized. In this case, it should be pointed out that gages employed in sampling material are not subjected to the same wear as those employed in the usual sorting or screening. Hence, through less inspection, the gage life will still be comparable to that of a gage used for more frequent gaging. Most firms now employ separate sets of gages for the shop and for inspection. Undoubtedly, the shop gages would incorporate all the present wear features. The inspection gages of the future, however, will have to be of a more accurate character, and will have to have the usual wear and gage maker's tolerances minimized.

III. **The Function of Portraying Quality Performance.** The function of portraying quality performance is two-fold. It involves the portrayal of quality at the machine and the reporting of overall results. The use of the control chart introduces a graphic means of showing the operator and supervisors as well as the quality control man just what quality is being produced. It has been said that one of the greatest advantages to accrue through the use of the control chart is the psychological advantage of showing the operator "where he has been and where he is going."

In addition, the control chart provides data which can be used immediately. Records, of course, are important. What **has** happened, however, makes comparatively little difference. It is what is going to happen that counts. Past data

are valuable only as they give clues for tomorrow, next week, or next year. The more time spent in burying the past, the less is left to live the future. Therefore, while collecting data has its proper place in quality control, it is the scouting around among the "hot facts," before they freeze into statistics, that makes quality control effective. There is no better source of these "hot facts" than the control chart. The control chart portrays quality performance where it will be most helpful, and unquestionably where it will do the most good.

However, there is the other function of quality control in the matter of reporting quality results on an overall basis. That is, there is required a reporting of quality data to evaluate the operational force. Objective data should be obtained that will show which operators are consistently producing good quality product and those that are contributing a high percentage of defective work. When it comes to questions of upgrading employees, quality data should be considered, and the quality control department should be in a position to supply such data.

In addition, there is the need for reporting quality data to the tool, engineering, planning, and other division of the business. In the last analysis there is no individual that holds a more key position than the quality control man. He is in a position to see the tools, gages, and special equipment in production, and to evaluate the results of their use in terms of the quality obtained. He is the one man who has the job of interpreting the quality specification to the shop, and then verifying this as the product is made. He has the opportunity of comparing the quality obtained against the quality desired. The quality control man observes the shortcomings of the shop as well as the lack of realism on the part of the engineering department in specifying what it wants produced. It is up to him to report discrepancies and to insist that the shop and engineering bring into their operations a greater degree of honesty in their efforts to produce as well as to specify the factor of quality.

It is essential that the quality control unit keep the planning department posted as to points where greatest scrap losses are encountered. Not only will this permit greater accuracy in ordering, but it will also insure delivery of a sufficient quantity at the time required.

In much of quality data reporting, it has become accepted practice to use a fraction defective chart. However, there is an increasing demand on the part of management for reports of quality performance which will show precisely what the **lack** of control is costing them. Top executives often complain that the fraction defective chart does not give them the kind of information they want. It does not tell them whether the 5% defective represents ten dollars or a hundred dollars. Although the fraction defective chart is highly useful in modern control technique, management is asking for reports which will translate this quality picture into dollars and cents.

Therefore, it behooves the quality control group to compile results in such a way as to show management very conclusively that there is dollar value in the use of quality control. In addition, it should be recognized that even with a high state of control there will still be scrap losses, and it is desirable to report these promptly in terms of dollars and cents as well as in percentages. An excellent system in this regard is one which uses the International Business Machines tabulating card. This system permits the recording of the scrap loss, rapid posting of values, and the reproduction of a report within a brief period of time, all of which gives such a dollar report the value of being immediately available for control purposes.

In general, it seems certain that management will never be completely sold on receiving a fraction defective chart as its sole report of the quality performance of the shop. On the contrary, management will insist more and more on having all of these data translated into cost figures.

IV. **The Function of Education and Training.** The last major function of quality control lies in the area of education and training. In its broad aspects, it should be training which will instill quality mindedness throughout the organization. In its limited interpretation, it means educating and training inspectors so that there is greater uniformity in interpreting and measuring the quality requirements of the shop.

The question arises as to where one starts training people to acquire the quality habit or to develop quality mindedness. Is it the sole job of the quality control unit? Can it be done without the support of management? The answer to both questions is, "No!" Maintenance of quality is the job of everyone. Training people to have respect for quality standards is similar to and as necessary as training people to have respect for law and order. Both result in advantages to the industrial community and to society. It is difficult to comprehend why so many people refuse to recognize the fundamental concept that a wanton disregard of quality standards ultimately affects costs, and that increased costs are definitely a collective disadvantage. Quality is everyone's job.

In this matter of education and training, management has a primary role to play. People are prone to follow the pattern established by those whom they respect, or those expected to provide leadership in society. The same is true in the industrial community. If management is lukewarm in its support of the quality concept, the line organization will undoubtedly reflect this attitude. If management takes a vacillating position in regard to a quality control program, again the shop will undoubtedly exhibit a similar attitude. For example, it is common experience these days to hear of industries which during the war had top-flight quality organizations, but which, in the post-war period, in a false economy move, are eliminating their inspection and quality control effort. It is difficult to comprehend how an industry can face increasing costs and competition, which are as serious as the problem of war production, and still feel it desirable to abolish its quality control effort. Not only are there inherent dangers in this policy from the standpoint of maintaining quality and competitive position, but there is also the damaging effect on the people who constitute the working organization. There is a just basis for them to question management's intent. They may well wonder if management is sincere in its desire

for quality production when they see a move which either eliminates or at least de-emphasizes quality.

Management has a responsibility which it cannot lightly disregard. Line supervision, following the lead of management, can and will sell quality by letting its decisions rest on the answer to the question, "What will be the effect on quality?" In turn, if the operational force sees that its supervisory group is giving consideration to quality, it will recognize that quality is a serious business.

To encourage shop participation, quality incentives can be established which need not always be monetary incentives. All too frequently the psychology of individuals is overlooked through failure to realize that employees respond to other incentives—a word of commendation, or a bit of recognition for a job well done. Again, not enough use is made of that competitive spirit which exists in all individuals, and which can be exploited so easily in getting people, individually and collectively, to compete with one another in the overall drive to obtain better quality.

The last question in regard to training is, "Who should do the training?" On the surface it would appear that the quality control personnel would be best qualified. Undoubtedly from a technical standpoint that is true. However, many industries today have elaborate training departments set up for this specific function with individuals skilled in the art of training. It might logically follow, therefore, that the training which is to be done should be handled by them, or at least should fall under their supervision.

Specific devices which can be employed in the training process involve the use of exhibits showing the product made and its various components. This can be most effectively shown by having it placed on a display truck and moved through the shop, staying for reasonable periods of time in each department or division. Many companies use quality trophies which are awarded to the departments that have the best quality record for specific periods. Other companies use the suggestion system effectively. That is, special emphasis is placed on those suggestions which are related to quality, and if a suggestion is made which has to do with the improvement of quality of product it is given a special award along with the usual reward that it might merit. All of these ideas are techniques for directing the attention and interest of employees to the problem of quality, and have an overall effect in creating an attitude of quality mindedness.

In summary, a quality control unit has the task of interpreting, controlling, and verifying quality through measurement and/or comparison with engineering specifications. In the performance of this task, it should provide protection, maintain process control, portray quality performance, and provide education and training which will develop quality mindedness.

Sampling Incoming Material

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SHAFER AND ASSOCIATES

[**Clinic 17**]

Introduction. The problem of sampling incoming material is at first glance rather simple, but as one begins to set up an incoming inspection program the complexity of the situation is realized. Much of this confusion arises from the lack of printed material on this subject and from the multiplicity of possible sampling systems that can be employed.

Sampling incoming material can be broken down into the following individual problems.

1. How can sampling be made random?
2. What sampling systems are to be employed (single, double, group sequential, or true sequential)?
3. What criterion shall be used to establish the acceptance procedure (AQL, AOQL, lot tolerances or a combination of these)?
4. What sampling tables, if any, are to be employed?
5. Are items or dimensions to be classified as to importance; if so what is to be the basis for classification?
6. What action is to be taken upon rejection?
7. What records are to be maintained?

(1) Random Sampling. All tables for inspection systems have one fundamental element in common, namely, that the sampling shall be random and representative of the lot in question. Unfortunately, in practice when incoming material is inspected, it is practically impossible to get assurance of random sampling. Pure randomness would require that every piece be equally likely to be drawn for a sample. Since incoming material is usually in several containers or boxes one is usually forced to perform stratified sampling; that is, removing a portion of the final sample from each box. Thus each box should be sampled equally in order to give a perfect stratified sample. There is a reluctance among inspectors to open all boxes for this accumulated sampling, but it is of utmost importance to effect a good sampling system that every effort be made to get a sample from each box or container. Often the excuse for not sampling each box is that, if rejection occurs, a box must be repacked for return to the vendor. This is not sound, because the rejection should be the exception and not the rule. Each shipment should be opened with the expectation of accepting the lot; therefore boxes should not have to be repacked. Sampling each box may require ad-

Table A: APPRAISAL OF FOUR SAMPLING PLANS

FACTOR	Type of Sampling			
	Single	Double	Group Seq.	True Seq.
Total cost of inspecting items	most expensive	more expensive	less expensive	least expensive
Variability of inspection load	constant	slightly variable	more variable	most variable
Sampling costs when items can be taken as needed	most expensive	more expensive	less expensive	least expensive
Sampling costs when all samples must be drawn at once; i.e. lot moving on conveyor	least expensive	less expensive	more expensive	most expensive
Accurate estimation of quality of a single lot. (If estimate is over several lots, type of sampling may not matter)	best	better	worse	worst
Amount of record keeping	least	less	more	most
Psychological; give lot one more chance	worst	worse	better	best
Protection afforded consumer and producer	Can all be made equal			

ditional handling by the inspector, but the greater assurance afforded should be carefully considered before pure stratified sampling is abandoned.

If one **must** elect not to open all boxes, there should be a definite procedure governing the number of boxes to be opened. A plan could be devised and an "operating characteristic" drawn showing the chance for not drawing a sample from a box which was a defective box. One thing is essential in the design of an incoming inspection system; it must embody clearly **written** procedures. Nothing must be left to the individual's judgment as to any phase in the procedure. Furthermore, everyone concerned with the procedure must be taught and "sold" the fundamental concepts and reasons for each action. It is only through complete co-operation of all personnel that a sound and adequate procedure will develop.

(2) **Choice of the Sampling System to be Employed.** The question of the advantages and disadvantages of single, double, group sequential, or true sequential sampling plans is the next problem confronting the engineer designing an incoming inspection system. For the benefit of those unfamiliar with this terminology, these systems will be briefly explained. Single sampling is the drawing of one sample containing a specified number of items from the lot, and based upon the inspection of the items in the sample, a decision is made either to accept or reject the lot. Double sampling involves two samples. One sample is initially drawn, and from inspection of this sample three decisions are possible: accept, reject, or take another sample. If another sample is required, inspection of this second sample will result in the decision either to accept or reject the lot. Group sequential, or multiple sampling as it is often called, is double sampling carried on several steps further; that is, the findings of the second sample could require a third sample, and this might force a fourth sample, and so on. This series of samples is usually truncated, and a decision to accept or reject is made at the fifth to seventh sample. True sequential is a system of sampling unit by unit, or one by one, until enough good units are found to accept the lot or enough bad units found to reject the lot.

Choice of a sampling plan requires a consideration of costs and practicability. Each system under certain circumstances is superior to all others. In an effort to enumerate some of the pertinent considerations involved, Table A was prepared and can be used as a guide in the selection of the most applicable system. Note in particular the last line of this table which calls attention to the fact that specified degrees of protection for both producer and consumer can be held constant in each of the four types of sampling plans.

The simplest of all systems is naturally a single sampling plan, but one sacrifices simplicity for cost. On the other hand the least costly system is true sequential, but here one sacrifices simplicity. The choice is up to the individual application. If the nature of the situation does not require single sampling, the best choice is between double and true sequential sampling. The reason for passing over group sequential is that it contains the evils of both double and true sequential, being more costly than true sequential and more complex than double sampling.

(3) **Criterion to be Used in Establishing an Acceptance Procedure (AQL, AOQL or Lot Tolerance P_t).** AQL is **acceptable quality level,** or that per cent defective which can be economically tolerated. Lot tolerance, P_t, is that per cent defective which is economically unacceptable. AOQL is **average outgoing quality limit,** and represents the per cent defective, on the average, of several lots which can be guaranteed as a top limit to the consumer. It must be borne in mind that AOQL is valid **only** if rejected lots are screened 100%. Hence, if rejected lots are returned to the vendor, it is impossible to use an AOQL concept. An inspector is continually confronted with two risks: (1) he can reject material of acceptable quality (AQL), or (2) he can

accept material of unacceptable quality (lot tolerance). The former is called the **producer's risk** and the latter is the **consumer's risk.** The Dodge Romig Sampling Tables have set as a standard a consumer's risk of 10% (1 time in 10 an unacceptable lot could be accepted), while the Armed Forces during the war set as a standard a producer's risk of 5% (1 time in 20 an acceptable lot could be rejected). These standard risks have been generally accepted by industry, and have proven satisfactory.

Every sampling inspection system has associated with it an **operating characteristic** curve, which shows the chance that a lot of any particular quality will be accepted. Figure 1 shows a typical operating characteristic for a sample of 50 with one defect allowed. Also shown, by way of explanation, is the AQL, lot tolerance, and the consumer and producer risks for this plan.

Every inspection plan also has an AQL, AOQL, and a lot tolerance, and although each is important to the engineer, present tables are made upon the basis of only one of these characteristics. This will be discussed under the next topic. However, in each case, a decision must be made by the engineer as to which concept he will employ, because this decision will force his use of specific sampling tables.

(4) **Choice of Sampling Tables to be Used.** Depending upon the decision of topic (3) the following choices are open to the engineer.

Criterion to be AQL:
- Use Army Ordnance Standard Sampling Tables;
- Use Navy Sampling Inspection Tables for AQL.

Criterion for AOQL (use only if rejected lots are screened 100%):
- Use Dodge Romig Sampling Tables;
- Use Navy Sampling Inspection Tables for AOQL.

Criterion to be lot tolerance P_t:
- Use Dodge Romig Sampling Tables.

If sampling system is to be single or double:
- Use Dodge Romig Sampling Table;
- Use Army Sampling Tables;
- Use Navy Sampling Tables.

If sampling system is to be group sequential:

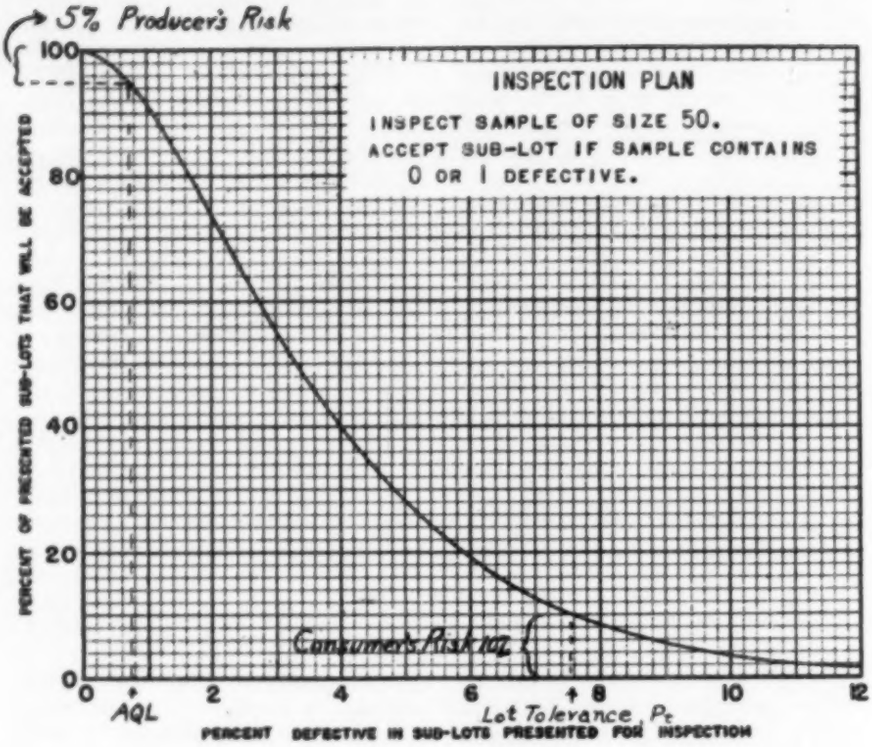


Figure 1: OPERATING CHARACTERISTIC CURVE

Use Navy Sequential Tables.

If sampling system is to be true sequential:

Design own system by reference to **Sequential Analysis of Statistical Data** published by Columbia Press.

There are no existing tables for true sequential sampling. The engineer must design his own plan, specifying the AQL, lot tolerance, and also the consumer's and producer's risks. This can be done by consulting the Columbia publication just referred to. It should be noted that in true sequential sampling the engineer formulates both risks, as well as AQL and lot tolerance, before the plan is made. Also the plan is made regardless of lot size. All present sampling tables are a function of lot size. If an engineer uses an inspection table based on AQL, then as the lot size increases, the lower end of the operating curve is drawn inward and the lot tolerance becomes smaller as does also the AOQL. On the other hand, if a table is used designating lot tolerance, then as the lot size increases, the upper end of the curve is pushed outward and the AQL increases as does the AOQL. When a plan is arrived at in tables based on AOQL, then as the lot size increases, the lower end of the curve comes inward while the upper end goes outward; that is, the AQL increases and the lot tolerance decreases.

The practice of allowing the lot size to change the operating characteristic curve is based upon the premise that less risk should be taken on the undesignated end of the curve for increased lot sizes. Certainly this is not standardization, which is the goal of a quality engineer, so in designing an incoming inspection plan some thought should be given to the following argument. The operating characteristic is standard only if the same number of items are drawn from every lot regardless of lot size. If the sample is more than 10% of the lot size, the hypergeometric law causes the operating characteristic to become more severe. But for most cases, drawing the same size sample each time creates a standard plan and operating characteristic. The ease of administering such a system should be apparent. There would be one set of inspection instructions for all, and the inspection reports would also be simplified. Perhaps risks should

be adjusted for type and cost of individual items rather than by lot size as is currently done. For example, items could be classified into price range A, B, C, D, etc., and a standard plan made for each range. To put such a plan into effect the quality engineer would decide on a proper operating characteristic curve giving attention to the expected AQL, AOQL, and lot tolerance. When adequate weighting of these criteria has been made, the plan is then used on all lots regardless of size. One of the greatest hazards of such a system, for all its merit, will be convincing the man that actually performs the inspection, and his supervisor, that this is an accurate procedure. It is indeed a difficult task to convince the laymen that sampling accuracy is dependent upon how many, not upon the ratio of sample size to lot size. One additional word of caution about such a plan is that randomness of sampling takes on extreme importance when this procedure is employed because one of the arguments in favor of increasing the sample size with lot size is to produce greater randomness of sampling.

(5) **Classification of Items of Dimensions as to Importance.** Although the question of classification is important in the design of incoming inspections, the installation of sound sampling procedure should not wait for these classifications to be made. It is better to initiate a program without classifications and let classification follow along when the sampling procedure is adequately understood. The reason for this is that good sampling is so important that its institution should not be retarded by any of the additional devices of quality control. Eventually the sampling technique will have to be taught to the inspector, so if he absorbs this first, then when classifications are made they will fall right in line and cause very little confusion.

When the time arrives for making classifications, the engineer can devise classification by **items** according to their eventual importance and ultimate cost. Such a scheme would be used with the program of standard sample size regardless of lot size as outlined in topic (4). The engineer can also classify individual defects and dimensions to be found on an item into various categories of importance, such as major, minor, and incidental. Then a different AQL, AOQL, or lot tolerance is assigned to each classification. When classifications are assigned, a decision must be made as to whether inspection is to be for defects or for defective pieces (defectives). A **defective** is any piece with one or more defects of the same classification, so a single piece might have three major defects but would still count as one defective, and the acceptance numbers of the plan would mean defectives. A single piece could also have a major, a minor, and an incidental defect. This would then count as one major defective, one minor defective, and one incidental defective, and would theoretically be scored as three different defective pieces. Thus, if inspection is for defective pieces, one must be sure that a unit rejected for, say majors, is also subjected to inspection for the other classifications and not just discarded. If it is discarded, obviously the sample size for the following classifications is smaller and the operating characteristic is not held constant for these classifications.

An inspection system based on defectives is much simpler to administer than one based upon defects, as will be explained, but often a supplier will argue against a system based upon defectives. He will contend that he is allowed a certain per cent of defective units, assume 1%, but he has ten dimensions to hold; consequently each must be held to .1% defective, which he may say can not be done. The purchaser takes the stand that he is paying for good pieces and not dimensions. Each argument is valid and worthy of consideration in designing an inspection system or operating characteristics. However, if inspection is conducted on defects the system becomes complex and the record keeping difficult, because an acceptable quality level is assigned to each dimension and inspected accordingly. It must be borne in mind in assigning AQL's to the various dimensions that these are additive, so that the resultant AQL for the piece is the sum of all the individual AQL's. This is an important point often overlooked in the design of an inspection system. For instance, if there are ten pieces going into a final assembly, and if each has an AQL of .5%, then the AQL of the final assembly becomes 5%. Therefore, AQL's should be assigned with the possible resultant AQL of the finished product in mind.

(6) **Action to be Taken upon Rejection.** When inspection yields the decision to reject a lot, the most desirable action, of course, is complete rejection and return of the lot to the vendor, with samples and reasons for rejection. However, in the current environment of a vendor's and not a purchaser's market, much caution should be exercised before a shipment is returned to the vendor. Nevertheless, there is nothing that will force a vendor to improve quality quite as much as rejection of a lot. This is especially true when the market is highly competitive. When it is impractical actually to reject a lot, at least a notification of substandard quality should be sent to the vendor. However, a rejected lot not returned to the vendor must be screened by the purchaser. Often 100% inspection will be in order. There exists one method of escaping this 100% inspection, and that is inspecting only enough of the rejected lot to raise the substandard quality to the AQL. For example, suppose the AQL is set at 1% and the lot is rejected by the sampling plan. If the sample gives evidence that the lot is 2% defective, the reinspection need be done on only half the lot, for this would then raise the quality of the lot to the required 1% defective. Naturally, before the lot would be accepted it must be accepted by the original sampling plan. This is a concept on which little work has been done, but it is certainly worthy of consideration and investigation.

(7) **What Records are to be Kept?** The basis of any control is the analysis of records, and control at incoming inspection is dependent upon adequate records. Correct records will indicate when inspection should be relaxed or made more severe. A vendor who has shown a past record of high quality and a process in a state of statistical control can have the inspection of his material relaxed, whereas a vendor of poor quality with a process out of control should perhaps be burdened with a more severe inspection criterion. By the analysis of records differences will often be detected in one's own in-

spection staff. In particular, on double and sequential plans an inspector who always accepts borderline quality, due to his reluctance to draw a second sample, can be detected and warned of his error.

Inspection records should be kept in some graphic form so that control limits may be applied. This can be by products or by vendor as may suit the particular need. Figure 2 is a copy of a form for this record. When times return to normal, and the purchaser can choose his vendor, these records should be submitted to the purchasing department for its analysis in selecting quality vendors.

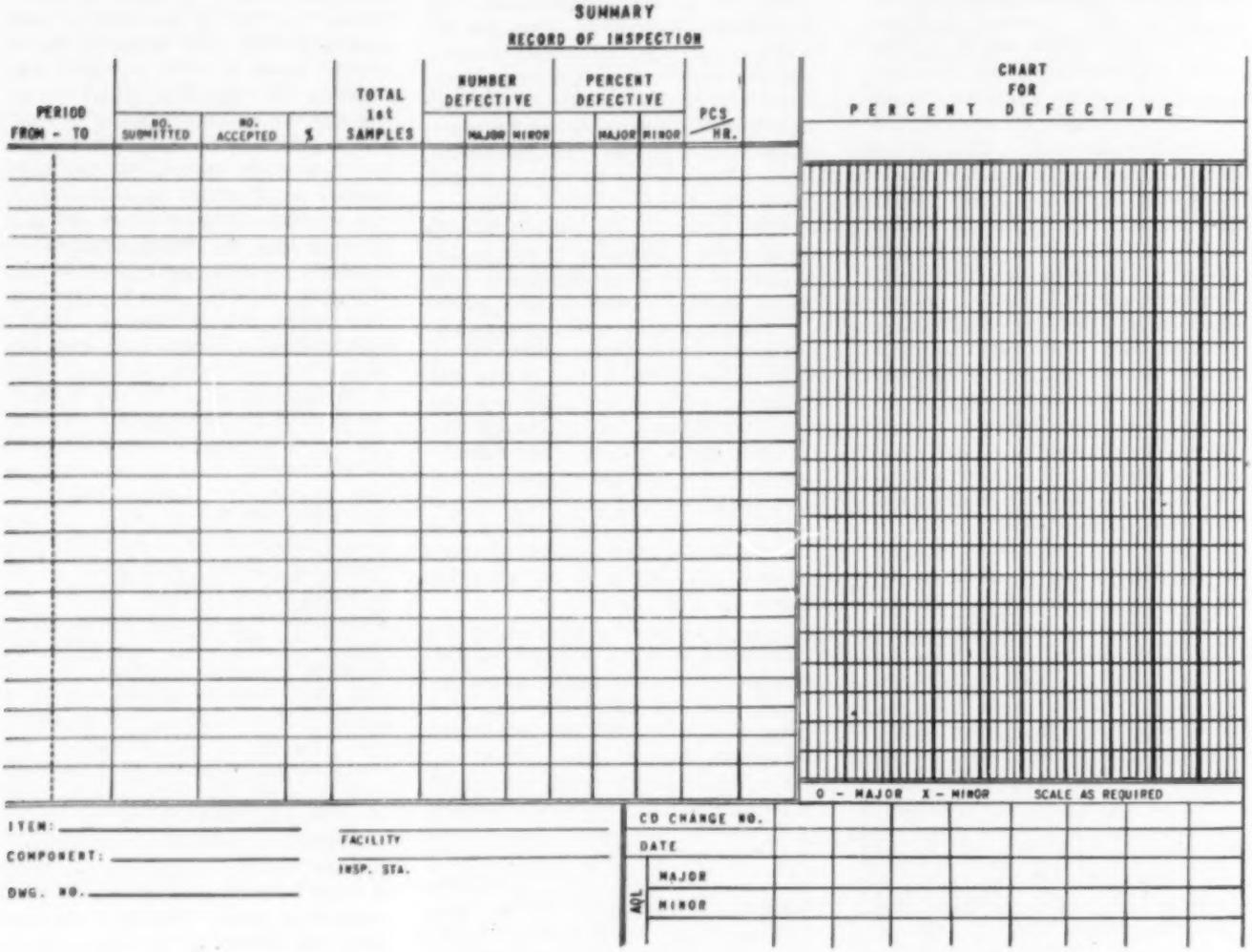


Figure 2

NOTICE

The next report of the Midwest Quality Control Conference will appear in the November issue. Additional copies of this issue, the July issue, and the May issue can be obtained at a price of $1.00 each. The complete Conference report will be available at a price of $4.00. Requests for individual copies or for reservation of complete sets should be sent to Martin A. Brumbaugh, Crosby Hall, University of Buffalo, Buffalo 14. Payment should accompany orders for individual copies. In placing orders for the complete report, please give mailing address so that we can send bill when the set is ready, either in December, 1946 or January, 1947.

Quality Control Conferences Arouse Wide Interest

A pioneering effort to further the wider and more profitable use of Quality Control methods is being sponsored through a series of conferences, held at Federal Products Corporation, Providence, R. I. First started as an experiment, the Conferences are well on the way to becoming a standard service. The effort is noteworthy for several reasons. No one denies the importance of Quality in forthcoming competition. Everyone is keenly alert to the need for reducing scrap and reoperation losses, as a direct lever to increased profits. It is also realized, somewhat vaguely perhaps, that too little use is being made of the rather new, but powerful technique known as Statistical Quality Control. It is also felt that more educational work in the technicalities of Inspection, Quality Control and Gaging is needed. The Conferences sponsored by Federal Products are intended to level out such valleys.

A unique feature of these Conferences has been the assistance given by a number of representative industrial concerns who have a primary interest in the progress of Quality Control as a standard industrial practice.

The first Conference was held August 13 to 16 and the second Conference on September 10 to 13 inclusive. J. B. Wilkie of the Pratt & Whitney Co. (Niles-Bement Pond Division) of Hartford, Conn. served as a "staff" member and helped head up discussions concerning proper gaging methods and applications in relation to Quality Control. Mr. Wilkie supplemented his presentation with practical demonstrations of gaging blocks, conventional gages and comparators.

The Taft-Peirce Co. of Woonsocket, R. I. collaborated by leading discussions on dimensional inspection and gaging equipment visualized by products of their manufacture. A discussion of thread gaging by J. H. Smith of Taft-Peirce was of special interest.

The Conference agenda included discussions on the management viewpoint toward Inspection and Quality Control, and to the exchange of ideas on the organization, routines, and maintenance of these vital elements in a factory organization.

The core of the Conference was, of course, Quality Control, and particularly the statistical technique. Something new was added here, in that each phase of Statistical Quality Control could be precisely demonstrated by practical shop examples. With receiving department, manufacturing, and assembly operations continuously proceeding in the plant it was not difficult to demonstrate, teach, and prove the practicability of any Quality Control procedure discussed in the Conference. C. W. Kennedy, Quality Control Engineer for Federal Products, led the Statistical Quality Control discussion and instruction sessions. I. A. Hunt, Advertising and Sales Promotion Manager, Federal Products led the discussion on "Indicating, Air and Electronic Gaging Systems." L. O. Heinold, of Federal Products gave a talk on "Gage Design."

Among those attending these Conferences were: J. F. Holbach, Corbin Screw Company, New Britain, Conn., David Berke, Corning Glass Company, Central Falls, R. I., W. A. MacCrehan, General Electric Co., Lynn, Mass., K. E. Gleason, Holtzer-Cabot Co., Boston, Mass., E. H. Banfill, Bridgeport Thermostat Co., Bridgeport, Conn., John Vanderpoel, New Departure Div., Bristol, Conn., Frank Seidler, Seth Thomas Clock, Thomaston, Conn., Edward Wehner, Marlin-Rockwell Co., Plainville, Conn., W. H. Wardle, Telechron, Inc., Ashland, Mass., Erwin Tooley, Porter-Cable Machine Co., Syracuse, N. Y., M. R. Wilson, Canadian Industries, Ltd., Montreal, Canada, Jack Stewart, Canadian Industries, Ltd., Montreal, Canada, F. S. Sussman, Chance-Vought Co., Stratford, Conn., E. Gittleson, General Cable Corp., Perth Amboy, N. J., H. Purdy, General Cable Corp., Perth Amboy, N. J., R. S. Pratt, Bridgeport Brass Co., Bridgeport, Conn., Phillip Allen, Scintilla Magneto Div., Sydney, N. Y., G. L. Smith, Bell Aircraft Co., Buffalo, N. Y., H. Phillips, Walworth Company, Boston, Mass., H. L. LePire, Capewell Mfg. Co., Hartford, Conn., J. Coyle, Bullard Co., Bridgeport, Conn., J. Day, Norton Co., Worcester, Mass., R. Anderson, Universal Winding Co., Providence, R. I., L. Bass, General Electric Co., Syracuse, N. Y., J. H. Mulhall, Polaroid Corp., Cambridge, Mass., E. J. Perry, Sylvania Electric Corp., Ipswich, Mass., C. M. Harman, Sylvania Electric Corp., Emporium, Pa., P. H. Geist, Manning, Maxwell & Moore, Boston, Mass., W. Robbie, Gorham Mfg. Co., Providence, R. I., N. T. Wright, Gorham Mfg. Co., Providence, R. I., T. Meegan, Grinnell Corp., Providence, R. I., G. F. Nyren, Clifford Mfg. Co., Boston, Mass., J. F. Brown, General Electric Co., Lynn, Mass.

The following is typical of the "staff" or Discussion Chairmen and their subjects:

Quality Control

R. A. Cotter,
Quality Control Engineer
U. S. Time, Inc.,
Waterbury, Conn.
W. R. Purcell
Quality Control Mgr., Lamp Div.
Sylvania Electric Products
Salem, Mass.

Inspection

C. J. Hudson,
Quality Manager
The Norton Co.,
Worcester, Mass.
John Greacen,
Chief Inspector
The Bristol Co.,
Waterbury, Conn.

Technical

C. J. Kirchen,
Statistician
Remington Arms Co.,
Bridgeport, Conn.
Arthur Wilder,
General Electric Co.,
Providence, R. I.

Management

Fred Stone,
Director of Enginpering
Wanskuck Mills,
Providence, R. I.
Dr. J. M. Juran,
Wallace, Clark Co. and
N. Y. University, N. Y. C.

Frequency Distribution vs. Acceptance Table

G. R. ARMSTRONG and P. C. CLARKE
QUALITY CONTROL ANALYST ASSISTANT GENERAL MANAGER
HUNTER PRESSED STEEL

The general problem of selecting a suitable procedure for sampling lots of material, particularly manufactured parts, as they are received from a vendor has attracted considerable attention. Because of the importance of this problem a study of the merits of the various available methods has been conducted by this company, the results of which indicate that special consideration should be given to the advantages offered by the use of frequency distribution sampling.

In any sampling system there are two general methods—

1. **Sampling by Attributes,** the purpose of which is to determine simply whether the product does or does not conform to some specified quality characteristic. For example, the product does or does not
   Pass the go-no-go gage
   Have burrs, scratches, dents, etc.
   Perform as required
   Contain defects, etc., etc.
2. **Sampling by Variables** involves the process of measuring or testing each individual piece in the sample to obtain the numerical value of the characteristic of each individual piece.

Sampling by variables is generally much more informative than sampling by attributes. However, in many cases there is no simple convenient unit measure of the quality characteristic in which case we must resort to sampling by attributes. There exists a wide field of application where either method can be used, the choice depending largely on the economic balance between the increased value of the information obtained in variables sampling and the lower cost of attributes inspection.

Sampling by attributes (per cent defective) is usually performed with the aid of acceptance tables involving single or double sampling plans or by the newer technique of sequential sampling.

The acceptance tables facilitate arriving at the desired sample size for a given lot of parts. In those cases where successive lots are being received over a long period of time and at frequent intervals, the sampling results may be used to determine the process average of per cent defectives which in turn makes it possible to select the smallest sample size which will assure that any particular lot will conform to a certain specified quality level. This is a rather important point to keep in mind since in many cases the number of lots received or the regularity with which they are received makes it impossible to determine the process average with sufficient accuracy in which event it may become necessary to use relatively large samples to assure conformity to the specified quality level.

Sequential sampling possesses the advantage of employing, on an average, a smaller sample size to determine whether the per cent defective in a lot exceeds a certain value. For the purpose of comparisons which will be made here sequential sampling can be assumed to be the same as acceptance sampling.

Sampling by variables involves preparing a simple frequency distribution of the measurements of the individual parts and/or using the control chart technique. While the control chart is used largely for control during production it is also successfully applied to incoming inspection as is pointed out later.

The problem of making individual measurements or tests on a sample comprising 50 to 200 pieces with a minimum expenditure of labor requires that the measuring or testing equipment be skillfully designed in order that repetitive measurements can be made rapidly with no loss of accuracy. This is exactly the same problem which must be faced wherever the control chart technique is employed.

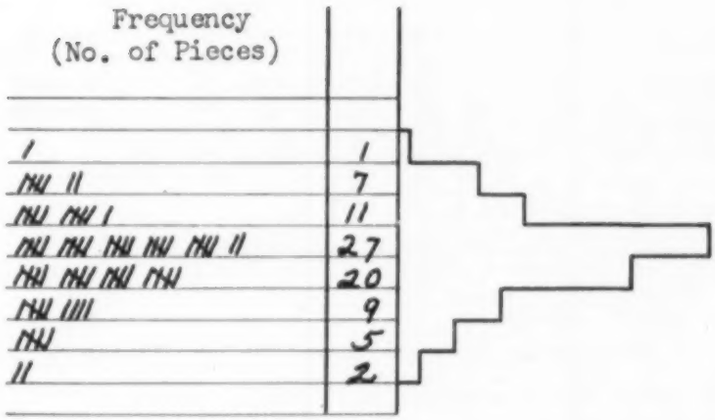
Because of the extensive use of control charts in the coil spring and stamping divisions this particular problem has received priority attention and has resulted in the design and construction of an entirely new line of measuring and testing instruments. This action, combined with careful examination of the technique of recording results of measurements, has made it possible to reduce substantially the cost of inspection.

In preparing a frequency distribution for a given characteristic of a particular part, the usual practice is to divide the readings into increments called cells. The size of increment or cell employed should be such that a total of between 8 and 16 cells contain measurements. Fig. 1 illustrates the frequency distribution in its simple form as recorded by the inspector making the measurements. In actual practice the piece is measured and the check mark is placed opposite the corresponding cell. Measurements proceed until a fairly well defined picture or pattern of the frequency of occurrence of the dimension is obtained. On the right side of Fig. 1 the same data has been converted to what is known as a frequency histogram, which form is used throughout the balance of the article for illustrative purposes.

In some cases it may be difficult to decide in advance the proper cell size to employ, particularly where the increment of measurement is small compared to the expected total spread of the values. In order to provide means for recording individual measurements and then assembling these values into a frequency distribution having the desired number of total cells the method illustrated by Fig. 2 can be employed. Sometimes it is highly desirable to keep a record of the individual measurements which purpose is automatically fulfilled by Fig. 2. In this example the data shown in Fig. 2, measured in increments of .0001, has been reassembled into the frequency distribution, cell size .0005, in Fig. 1.

Fig. 1

Range	Cell Midpoint	Frequency (No. of Pieces)
.2485 - .2490	.24875	
.2490 - .2495	.24925	1
.2495 - .2500	.24975	7
.2500 - .2505	.25025	11
.2505 - .2510	.25075	27
.2510 - .2515	.25125	20
.2515 - .2520	.25175	9
.2520 - .2525	.25225	5
.2525 - .2530	.25275	2
.2530 - .2535	.25325	



Range	Means
.2485 - .2490	.2485000... - .2489999...
.2490 - .2495	.2490000... - .2494999...

Fig. 2

	0	1	2	3	4	5	6	7	8	9
.2490			1			1	11		111	1
.2500	11	11	1	11	1111	5+1	1111	111	5	5+1111
.2510	5+11	5	111	11	111	111	111	11		1
.2520	111	1	1			1		1		
.2530				*						

* The dimension of a part recorded in this cell would be between .25330 and .2533999 - - - -

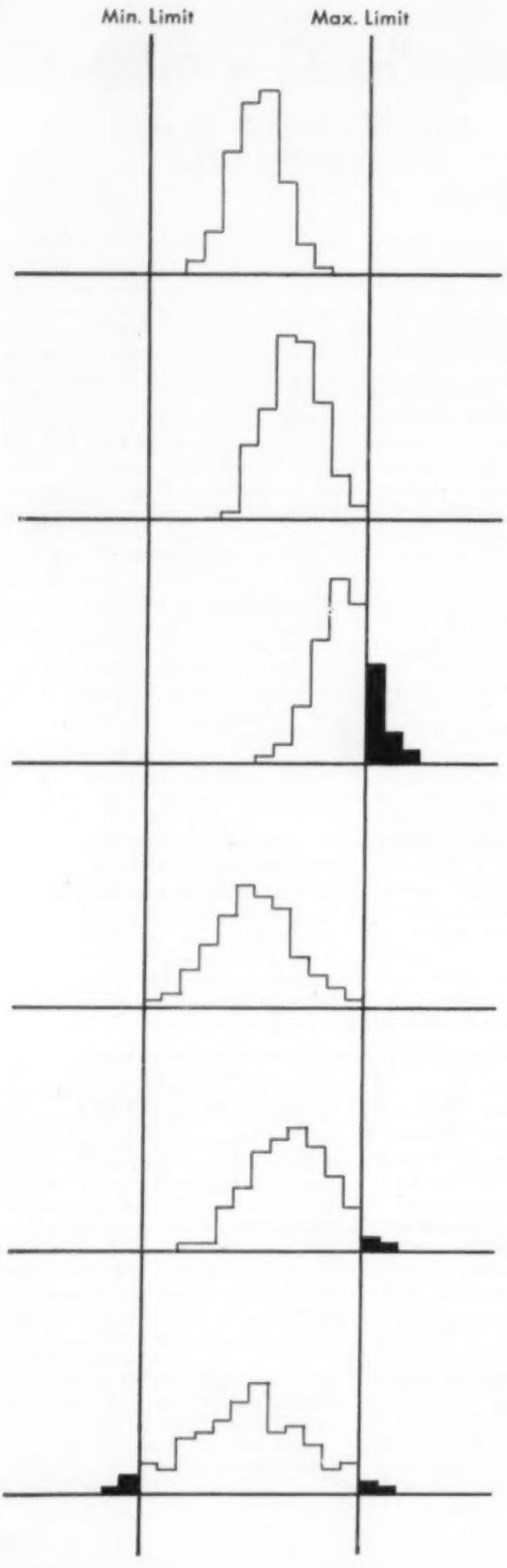


Fig. 3

Product range substantially less than specified and distribution is well centered. Consider using smaller sample on subsequent lots.

Fig. 4

Product range substantially less than specified but distribution is off-center. Production of defects imminent.

Fig. 5

Product range substantially less than specified but distribution is badly off-center producing defects above max. limit. Vendor can meet tolerance and eliminate defects by centering the distribution.

Fig. 6

Product range approximately same as specified and distribution is well centered. Slight shift off-center will produce defects at one limit. Vendor may require increased tolerance.

Fig. 7

Product range approximately same as specified but distribution is off-center producing defects above max. limit. Vendor must reduce product range through change in process or by better control and distribution must also be centered. May require increased tolerance.

Fig. 8

Distribution is well centered but exceeds specified range and defects are occurring at both limits. Change in process or better control required to reduce range. Vendor may require increased tolerance.

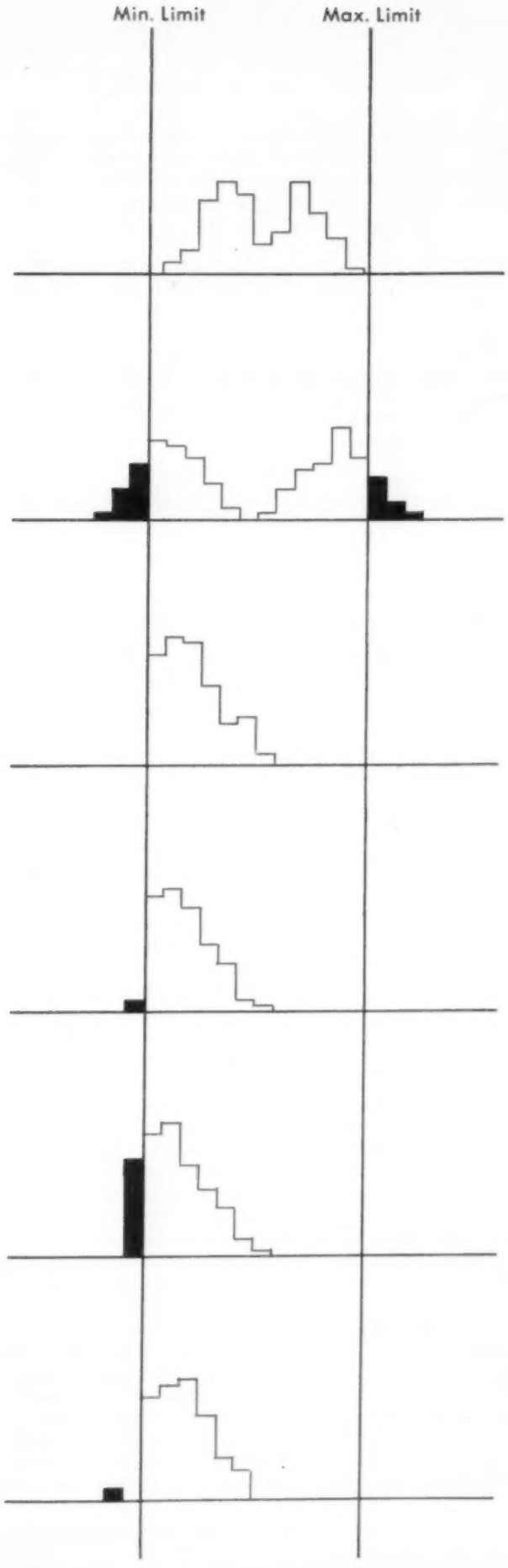


Fig. 9

Double distribution suggests possibility of (2) sets of tools, change in process or material during running of this lot. Vendor can easily hold tolerance since range of either distribution is smaller than specified.

Fig. 10

Same as Fig. 9 except that the two centers are far enough apart to cause defects outside both limits. No increase in tolerance needed. Condition should be easily corrected.

Fig. 11

Distribution off-center to min. limit and lot has been inspected 100% before shipping. If production is centered vendor may be able to eliminate the 100% inspection.

Fig. 12

Same as Fig. 11 except operator is passing defects or gage is slightly off.

Fig. 13

100% inspection gages are probably not set to correct limits and defects appear below the min. limit. Operator may be having difficulty deciding borderline cases.

Fig. 14

Same as Fig. 11. Gages set correctly but operator has missed some parts.

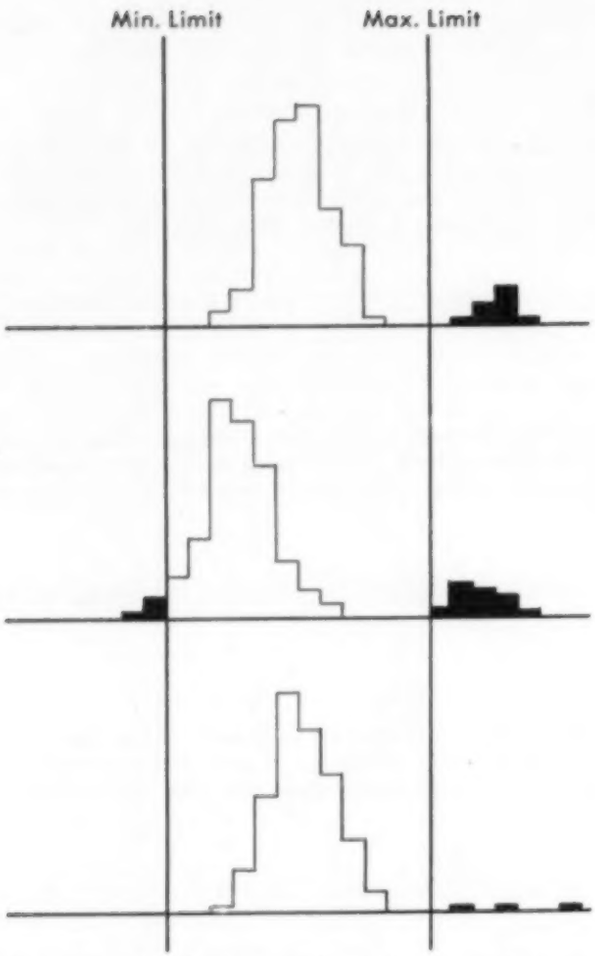


Fig. 15

Principal distribution has narrow range and is well centered. Small distribution above max. limit may be parts from tool and set-up tryouts not set aside. Vendor should be able to ascertain cause and correct condition.

Fig. 16

Similar to Fig. 15 except main product distribution is off-center to min. limit producing defects outside both limits. Vendor should be able to correct condition. No increase in tolerance required.

Fig. 17

Distribution has narrow range and is well centered. A few individual pieces are exceeding max. limit. May be due to misses by operator or machine. Vendor should have no difficulty in overcoming this condition.

frequency distributions such as illustrated are extremely simple to obtain and experience has shown that shop personnel, in almost any labor grade, have no difficulty in understanding and appreciating these simple dimensional pictures.

The accompanying series of figures together with explanatory remarks should serve to illustrate clearly a number of the advantages which the frequency distribution sampling procedure possesses over per cent defective or acceptance sampling.

Acceptance sampling in which only the number of defects is determined would supply only the following information.

1. No defects—Fig. 3, 4, 6, 9, 11.
2. Defects at one limit—Fig. 5, 7, 12, 13, 14, 15, 17.
3. Defects at both limits—Fig. 8, 10, 16.

By way of comparison the frequency distribution not only supplies the same information but also enables intelligent interpretation of the probable cause for the defects. In many cases it will be possible to ascertain correctly how the defects can be eliminated despite the fact that we may have no knowledge regarding the vendor's manufacturing process.

The efficiency of frequency distribution over acceptance sampling in dealing with vendors is particularly evident in those instances where incoming inspection finds defects outside of both limits. The natural reaction of the vendor in this situation is to request increased tolerances. However, with frequency distribution sampling such requests may be shown to be not always justified. For example in Fig. 8 the distribution while well centered runs outside both limits suggesting that an increase in tolerance may be in order, although investigation (by the vendor) may show that a change in the process will result in a narrower distribution. However, in the case of Fig. 10 and 16 the distributions clearly demonstrate that the tolerances specified can be held. On the other hand, acceptance sampling would not be able to differentiate between these three cases so that there would exist no basis for a decision when the vendor requests an additional tolerance spread.

It has been found by transmitting to the vendor a photostatic copy of the results of a frequency distribution sampling of his product that much better cooperation in removing the causes of out-of-tolerance production results. Besides providing a better basis for reaching a decision as to whether the quality of a particular lot is such that it can or cannot be used, it also helps in deciding questions regarding the desirability or feasibility of increasing or decreasing tolerances.

As experience is gained with frequency distribution sampling another of its important advantages will become evident. In sampling a given lot of parts the size of sample required to obtain a good indication of the quality will depend very greatly on the relationship of the lot distribution to the specified limits. Where the quality of the lot is high the num-

ber of pieces which must be measured to demonstrate that fact will be found to be low. The sample size and, therefore, the amount of effort expended in sampling is always a minimum and just sufficient to reach an intelligent decision regarding the lot quality.

Where shipments are being received at a reasonably regular rate the control chart technique can be used to effect appreciable savings in inspection time and cost. This procedure involves sampling a few of the original shipments with the larger sample size and using the data obtained from the frequency distributions to compute control and reject limits for following lots. On following lots a sample comprising only some 5 to 10 pieces would be used. In the event that the control chart subsequently indicates a questionable lot then the sample size on that particular lot would be immediately increased to obtain a full frequency distribution.

While sampling tables are also used by the Inspection Department wherever deemed desirable the more general practice is to sample by variables and obtain the frequency distribution. This method was first used in 1932 in the analysis of manufacturing variations and in obtaining inspection tolerances for the coil spring department. Starting in 1936 it was applied extensively in the incoming inspection of parts for radio assemblies. The method proved successful and was subsequently standardized and applied to all incoming inspection. As would naturally be expected the same procedure is employed in final sampling of the quality of the **outgoing** product although the amount of such inspection required has been substantially reduced through the control charting of production.

Presenting Quality Control to Machine Operators

J. F. VERIGAN

QUALITY CONTROL ENGINEER, VALVE & JET DIVISION, THOMPSON PRODUCTS, INC.

(Editor's Note: Mr. Verigan wrote this article as a vehicle for introducing the concepts of quality control to machine operators. It is reproduced here with the expectation that other quality control engineers, facing the task of securing cooperation at the machine operator level, may find it useful.)

In a relatively short time, the words "Quality Control" have been heard more and more frequently. Since the term is somewhat new, there is some lack of understanding as to just what it means. Perhaps answering some questions which are commonly asked will provide a better picture of the real purpose of quality control.

What is Quality Control?

Quality control by statistical methods is simply the application of time-tested statistical theories to the economic control of quality in industry. It is based upon the idea that the best way to reduce or eliminate defects in the final product is to eliminate the original causes of such defects. It is usually less costly to follow this method than to allow defects to be made and then "inspect out" the bad material. Thus, quality control is primarily concerned with the manufacturing process. Once, through the data obtained in this manner, the manufacturing process becomes so improved that it has greatly reduced the defects being made, quality control places in the hands of the inspector a tool with which he can ascertain whether or not the process remains in this desirable condition.

Quality control by statistical methods is not a cure-all for every process ill. It is a scientific tool to be placed in the hands of trained people. It should be used in this fashion, as any other tool. A screwdriver should not be used to do the work of a wrench. Similarly, quality control need not be used where other methods are indicated.

Briefly, what are the methods used in Quality Control?

The initial procedure of a quality control engineer in setting up a quality control system is to make an accurate analysis of the process or methods currently being used. In doing this, he takes samples from a machine, tabulates measurements of these samples, and analyses these data by use of statistical methods. The answer he receives tells him at what average size or level the machine is being presently operated; it tells him the amount of variation in the machine itself; it tells him whether or not the operator is setting his size correctly, etc. For instance, where two machines are doing the same operation, it is often found that one operator adjusts his size to the high side, the other operator adjusts his to the low side. This causes trouble in subsequent operations because of the two different sizes. Quality control will pick out these differences in operation and ascertain which is the best side to work to. Both operators can then be taught how to work to the same size.

When the data are collected and analyzed, it will show whether or not the machine, in its present condition, will produce work within the tolerance desired by the engineers. If it will, control limits can be set and the process held at a uniform level. If not, it indicates that either the machine will have to be improved or the present tolerances widened.

"Control Limits" are frequently mentioned. What are they?

Control limits are limits arrived at by study and analysis of data obtained from the process. These control limits are set up to be the guide posts to indicate when to look for trouble, and when not to spend time looking for trouble. In every process or machine, there is a certain amount of variation which cannot be controlled by the operator. These chance variations may be such that they will still allow work to be made within the drawing limit. The control limits are designed

to show when these chance variations are at work and to show when some outside force, in addition to the chance variation, enters the process. This provides the opportunity to eliminate the outside force and return the process to its usual chance variation level.

Technically, the control limits are usually set up for averages. That is, any action is taken on the basis of an average of samples, say five pieces. This is based on scientific knowledge of the way in which averages behave.

The control limits are so designed that when an average of pieces is found directly on the control limit (which means the machine should be reset) there is a high degree of probability that no work has been produced outside the blue print limit.

What benefits are derived from Quality Control?

A few of the benefits derived from quality control by statistical methods can be listed below:

1. Reduction of scrap or rework.
2. Reduction in down time on machine operations.
3. Increase in output.
4. Reduction in inspection cost.
5. Improvement in product quality.
6. Increase in quality assurance.
7. Rationalization of specifications.
8. Increase in good-will of customer.

Space will not permit to prove all these points. Actual figures are available from a great many companies presently using quality control to show that savings are being realized because of these reasons.

Perhaps one of the greatest benefits to be realized, in addition to actual savings noted above, is the fact that all work is made at a uniform level during the process. This aids each operation and effectively reduces the down time necessary to re-set machines to take care of non-uniform work.

Why is Quality Control necessary?

Business is entering a highly competitive stage. The reduction of cost is of primary importance, while maintaining desired quality standards. To reduce cost by lowering quality will in the end, lose business. So quality control strives to maintain a desired quality standard, at the same time reducing cost.

Has Quality Control been time-tested?

For many years, perhaps twenty or twenty-five, a few large companies, such as Bell Telephone, Westinghouse, etc., have been using these methods. The Bell Telephone Company is largely responsible for their many applications to industrial problems.

Since the start of the war, due to pressure from the Armed Services for high quality material, many other companies have used these methods. To date, possibly 1,200 large companies have used them and have published results of savings and benefits derived from their use. These savings amount to hundreds of thousands of dollars in many instances.

What does all this mean to the machine operator?

Quality is built into the product by each operator. The success of any quality control plan depends largely upon how well the operator understands and cooperates in this program. It will give him a guide-post to set size, with a picture of where he has been and where he should be in order to maintain a uniform product. Feeling that each skilled operator is desirous of producing good, uniform parts, the quality control engineer places in his hands the tools with which to accomplish this. The success of the program depends upon the way in which each operator responds.

If each operator cooperates, the result will be reduction in cost, which will bring business, increased production, and greater job security for all.

Quality Control for the Engineering Student

JOHN A. HENRY

ASSISTANT PROFESSOR OF MECHANICAL ENGINEERING, UNIVERSITY OF ILLINOIS

The rapid growth in the use of statistical methods of quality control during the war years is resulting in a new field of education. The intensive and evening courses for men already in industry have only scratched the surface, as far as the need for trained men is concerned, and both industrial men and educators are now looking to the engineering colleges for a solution.

The solution is not simple. Engineering curricula are already crowded, with continuous pressure being brought to bear on them for the addition of more technical and liberal courses. When it is remembered that the main purpose of an engineering education is to provide a broad background of principles rather than narrow specialized training of the trade school type, it is little wonder that the faculty of many institutions may be skeptical about the approval of such a subject as quality control. Doubtless their predecessors felt the same way about the work of Frederick Taylor and the development of the internal combustion engine. These have found acceptance in the usual mechanical engineering curriculum, as have new ideas in other fields. The moral seems to be that, if Industrial Quality Control is here to stay, it too will be accepted. With that assumption in mind, let us proceed to see what may be done, and if possible, not allow supply to lag too far behind demand.

It might be well to examine the reasons for making such a course available to engineering students. The answer appears to be obvious. They have a sound background in drawing, mathematics, physics, chemistry, statics, dynamics and properties of materials. Many of them, including mechanical engineers, have a basic understanding of manufacturing processes and machine design. On the other hand, mathematics majors have no industrial background except by chance, and while commerce stu-

dents may have a better grasp of economic fundamentals than their engineering brothers, they too lack the practical and theoretical background. Where else should we look for likely candidates for the industrial field?

A Basic Course

Should a course in mathematical statistics precede a course in quality control? Few would argue the desirability of such a sequence, but many might question the necessity, and most, the possibility of including it in an engineering curriculum. It looks as though for the present at least formal statistics must be shoved aside. Parenthetically, the time may come when a course in mathematical statistics for engineers may have as much support as has differential equations today. That will come as the result of the demonstrated value of applied statistics courses such as quality control.

Having agreed on a basic course of an applied nature, it would probably appear in the junior or senior year. It would consist of the necessary basic statistical concepts, plus material given in the intensive courses: control charts, standard and sequential sampling, plus elementary correlation and applications to engineering specifications and design. The course should include at least a passing glance at the organization and coordination of production, research, development and inspection departments. If possible, some time should be spent on the vast field of instrumentation and measurements beyond that given in the usual college shop courses.

All engineers would not want or need such a course. It might be required of all men in industrial or production engineering, and be an option for those in other fields, particularly in ceramic, chemical, mechanical, electrical, and metallurgical engineering. Men who are interested in production and management and those whose interest lies in the fields of research and development would find such a course profitable.

An Advanced Course

For a select group who might be interested in further development, an advanced course should be available, largely of a statistical nature, and dealing with such subjects as correlation, analysis of variance, and significance tests. This course would have to be worked out in connection with the basic course in such a way that they would complement each other, and make unnecessary a course in elementary mathematical statistics for the engineer. These two courses should be designed and taught so that they could be taken with profit by students whose major fields are in mathematics, commerce, or the basic sciences, as well as in engineering.

It must not be inferred that the widespread adoption of such courses would solve the need for trained men overnight. Comparatively few students would elect them at the start, and of those who did, many would have no idea of making quality control a life work. Nor would a passing grade be an indication that the student possessed the necessary strength of character and tact that are prerequisite for a successful career. Opportunity for summer work in quality control for men who have completed the basic course might be one way to interest prospective future employees.

The Teachers

Who should teach these courses? It seems advisable that the basic or applied course should be taught by someone who is in close touch with the industrial field of quality control. It makes little difference whether the teacher be an engineer, mathematician, or economist by name, so long as he uses the engineering approach, makes use of the student's basic knowledge and interests, and is capable of presenting the mathematical background necessary for the advanced as well as the basic course. Securing these teachers will not be an easy task. While a college may, of necessity, occasionally request an untrained man to teach an established subject with standardized outlines and recognized textbooks, the same could not be done with an uncharted educational field like quality control. The course offering would drown with the students and instructor.

The advanced course, on the other hand, should be taught by a statistician who understands and is in sympathy with the applied field. He too should have contact with industry.

Mathematics Students

The mathematics student has been mentioned in connection with these hypothetical courses. Should he take a course in quality control at all? If the distinction was always drawn between the functions of a quality control man and those of an industrial statistician, much of the misunderstanding now existing in industry would be cleared up. The value of an applied course to a mathematics student and to his prospective industrial employer should be accepted without question. His limited engineering background may keep him from being a success in the shop, but he may still be of invaluable aid to the shop man. Those of us who are engineers will have to admit that new developments in the field will largely come from mathematical statisticians, as they have in the past.

The A. S. Q. C.

What should the American Society for Quality Control do about this matter? Educators are notoriously allergic to pressure groups, having seen so many fads come and go; but in this new and promising field they are going to need and appreciate some sound advice. The Society is the natural spokesman for quality control. It should be able to arrive at some reasonable, flexible conclusions as to the place and methods of teaching industrial quality control in the colleges of the country, and to set up standards to safeguard both the students and industry. It should also, perhaps, prepare to assist in providing adequately t r a i n e d teachers by the promotion of special training programs and by giving teachers opportunity to feel the industrial pulse through summer work. The Society must work fast, however, for pressure is developing rapidly for some kind of action, both by industry and by the engineering students themselves.

Summary

The rapid development of statistical quality control is bringing demands for formal college training for engineers. While difficult, such courses could be included in many curricula. A basic applied course in engineering should be followed by a more theoretical and advanced course in mathematics. The American Society for Quality Control must assume the leadership in setting up standards of teaching and course material, and be prepared to assist in the development of competent teachers.

LOCAL SOCIETY REPORTS

Indiana Society for Quality Control

At a meeting of the Society held on June 18, the following officers were elected to serve for the ensuing year: Mr. Arthur Bender, President, Delco-Remy Division, General Motors Corporation, Anderson, Indiana; Dr. Irving W. Burr, Vice-President, Assistant-Professor of Mathematics, Purdue University, West Lafayette, Indiana; Mr. William A. Shideler, Secretary, Assistant Quality Engineer, Stewart-Warner Corporation, Indianapolis, Indiana; and Mr. Carl E. Hoover, Treasurer, The Perfect Circle Company, Hagerstown, Indiana.

Also at this meeting, the decision was made to form a separate local organization in the Fort Wayne, Indiana area. Since that time, application has been made by that group to affiliate with the Indiana Society for Quality Control.

Another order of business was to plan the meetings for the coming year. It was decided that meetings are to continue to be held on the second Tuesday of every month, with three meetings to be held in Indianapolis, and the alternate three meetings to be conducted by visiting various plants employing quality control throughout the state.

Society for Statistical Quality Control Metropolitan New York Section American Society for Quality Control

The first meeting of the Society will be held at the Essex House, Newark, New Jersey, at 8:00 p.m., Tuesday, October 22, 1946. In opening the 1946-47 year, Mr. Andrew I. Peterson, Manager of Quality Control, Radio Corporation of America, is the Chairman, the subject under discussion to be "Practical Application of Quality Control." A speaker and several commentators are being secured to cover adequately some of the more important phases relating to the application of quality control techniques. It is expected that this practical approach will arouse the interest of the entire membership.

The year's program will cover many fields of interest, taking into account the varied interests of the membership. Specialized fields of interest, such as textiles, steel, vacuum tubes, will be covered. Plans are being completed to have one evening devoted to a coverage of the most recent work on some of the newer methods. One evening is to be devoted to a series of short papers contributed by the membership to give everyone an opportunity to present his or her ideas to the Society.

Two joint meetings are planned, one with the Newark College of Engineering and one with the Society for the Advancement of Management. An all day meeting will be held at Princeton University. A Saturday was selected so that most of the members would be able to attend. A special committee is working on this feature.

Three of the meetings will be held at the Engineering Building in New York since many of the members live in Westchester and Long Island, as well as in the City of New York. The places and dates of meetings are as follows:

Tuesday, October 22, 1946
Essex House, Newark, New Jersey.

Friday, November 22, 1946
Engineering Building, New York, New York.

Friday, December 13, 1946
Newark College of Engineering, Newark, New Jersey.

Saturday, December 14, 1946
Princeton University, Princeton, New Jersey.

Friday, January 24, 1947
Essex House, Newark, New Jersey.

Friday, February 28, 1947
Engineering Building, New York, New York.

Wednesday, March 19, 1947
Essex House, Newark, New Jersey.

Friday, April 25, 1947
Engineering Building, New York, New York.

Thursday, May 22, 1947
Essex House, Newark, New Jersey.

Michigan Society for Quality Control

At a midsummer meeting held August 1 in airconditioned Rackham Hall in Detroit, Dr. Edwin G. Olds, Carnegie Institute of Technology, presented "Latest Developments in the Field of Statistical Quality Control." Mr. Clarence Kooistra, Hoover Ball and Bearing Co. presented a condensed report of the June 7 Forum.

Society for Quality Control State University of Iowa Group

The Society will hold four meetings, each of two day's duration, during the coming year. The first of these will be held at the John Deere Tractor Plant at Waterloo, Iowa, October 11 and 12. Subsequent meetings will be held in December, 1946, January, 1947, and May, 1947 at places which will be announced later.

The officers of the Society are engaged in a campaign to make known to various firms, who have sent students to the several quality control courses given at Iowa State, the advantages of affiliation with the local Society and the American Society. This campaign should produce a sizable expansion in membership.

Quality Control Engineers of Rochester

The September 17 dinner meeting of the Society at the Chamber of Commerce was attended by 147 members and guests. The speaker, Dr. Martin A. Brumbaugh, Editor, INDUSTRIAL QUALITY CONTROL, traced briefly the early and more recent history of quality control development, presented specific examples of wartime uses of the technique, and completed with a penetrating analysis of the postwar trend toward the use of control technique in nonmechanical industries as well as the new balance between cost, quality and price which industry faces.

Society for Quality Control Northeastern Indiana

The speakers at the June 12 meeting were Mr. R. D. Long, International Harvester Company, and Mr. Keith E. Ross, General Electric Company.

The first three meetings for the coming season to be announced by our local society are as follows:

Sept. 11, 1946—Mr. H. B. Marsh
Subject—"Use of Statistics in Forecasting Demand"

Oct. 9, 1946—Mr. C. A. Bicking
Subject—"Quality Control in the Chemical Industry"

Nov. 13, 1946—Mr. F. J. Halton, Jr.
Subject—"Introducing Quality Control to Management"

AMERICAN SOCIETY NEWS

Changes in Board of Directors

Since publication of the roster of the Board of Directors in the May, 1946, issue, a number of changes have occurred. The Board is now composed of the following:
President: George D. Edwards
Vice-President: Andrew I. Peterson
Executive Secretary:
Ralph E. Wareham
Treasurer: Alfred L. Davis
Chairman, Editorial Board:
Martin A. Brumbaugh
Boston: Charles J. Hudson
Buffalo: Alfred J. Winterhalter
California: John M. Howell
Chicago: Ernest H. Robinson
Delaware: Arthur R. Kalmbacher
Georgia: Ralph A. Hefner
Hartford: S. G. Johnson
Illinois: Roman M. Hammes
Indiana: Harry B. Marsh
Iowa: Frederick J. Halton, Jr.
Michigan: Herbert G. Winter
Milwaukee: Bernard F. Litzau
Newark: Paul S. Olmstead
Northeastern Indiana: K. E. Ross
Ohio: Wade R. Weaver
Omaha: Carl W. Helmstadter
Philadelphia: Harry W. Poole
Rochester: Halsey H. Kent
Syracuse: Richard W. Coolbaugh
Western Massachusetts:
Morton M. Newcomb
The Pittsburgh and Saint Louis Sections have still to appoint Directors.

Committee on Membership Completed

Appointment of the following Committee on Membership is announced:

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Warren R. Purcell,
Regional Chairman
Dean Ayer
Lewis C. Young

Middle Atlantic
Richard L. Shire,
Regional Chairman
Arthur R. Kalmbacher
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Kort K. Pfabe

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Regional Chairman

Committee On Relations With Educational Institutions Completed

Appointment of the following Committee On Relations With Educational Institutions is announced:

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Executive Chairman:
A. C. Richmond

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George A. Andrews

Middle Atlantic
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